Health Consultation

Exposure Investigation

Evaluation of Exposure to Contaminants in Private Residential Water Supplies in Dimock, Pennsylvania

DIMOCK RESIDENTIAL GROUNDWATER SITE

Dimock, Susquehanna County, Pennsylvania

Cost Recovery Number: 3ATA00

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U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Agency for Toxic Substances and Disease Registry
Office of Community Health and Hazard Assessment
Atlanta, Georgia 30333

Health Consultation: A Note of Explanation

An ATSDR health consultation is a verbal or written response from ATSDR to a specific request for information about health risks related to a specific site, a chemical release, or the presence of hazardous material. In order to prevent or mitigate exposures, a consultation may lead to specific actions, such as restricting use of or replacing water supplies; intensifying environmental sampling; restricting site access; or removing the contaminated material.

In addition, consultations may recommend additional public health actions, such as conducting health surveillance activities to evaluate exposure or trends in adverse health outcomes; conducting biological indicators of exposure studies to assess exposure; and providing health education for health care providers and community members. This concludes the health consultation process for this site, unless additional information is obtained by ATSDR which, in the Agency's opinion, indicates a need to revise or append the conclusions previously issued.

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Prepared By:

U.S. Department of Health and Human Services
Agency for Toxic Substances and Disease Registry (ATSDR)
Office of Community Health and Hazard Assessment
Atlanta, Georgia 30333

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Abbreviations and Acronyms

ATSDR	Agency for Toxic Substances and Disease Registry
Bgs	below ground surface
CDC	Centers for Disease Control and Prevention
COC	Contaminant of Concern
CREG	Cancer Risk Evaluation Guide
CV	Comparison Value
DCHI	Division of Community Health Investigations
DMP	Data Management Plan
DOI	Department of the Interior
DRO	Diesel Range Organic
DTSC-HERO	California Department of Toxic Substances Control, Human and Ecological Risk Office
DWL	Drinking Water Level
EB	Eastern Branch
EDB	1,2-Dibromoethane
EI	Exposure Investigation
ELCR	Excess Lifetime Cancer Risk
EMEG	Environmental Media Evaluation Guide
EPA	(U.S.) Environmental Protection Agency
EPC	Exposure Point Concentration
ERG	Eastern Research Group
GRO	Gasoline Range Organic
HC	Health Consultation
HEM	Hexane-Extractable Materials
HQ	Hazard Quotient
IARC	International Agency for Research on Cancer
IOM	Institute of Medicine
IRIS	Integrated Risk Information System
IUR	Inhalation Unit Risk
LEL	Lower Explosive Limit
LOAEL	Lowest Observed Adverse Effect Level
MCL	Maximum Contaminant Level
$\mu g/m^3$	Micrograms per cubic meter
mg/m^3	Milligrams per cubic meter
µg/L	Micrograms per liter
µg/dL	Micrograms of lead per deciliter of blood
mg/L	Milligrams per liter
MCL	Maximum Contaminant Level
MCLG	Maximum Contaminant Level Goal
MDEQ	Michigan Department of Environmental Quality
MRL	Minimal Risk Level
NCEH	National Center for Environmental Health
NHANES	National Health and Nutrition Examination Survey
NLM	National Library of Medicine
NOAEL	No Observed Adverse Effect Level
NRC	National Response Center
NTP	National Toxicology Program
OMB	Office of Management and Budget

PADEP	Pennsylvania Department of Environmental Protection
PADOH	Pennsylvania Department of Health
PAH	Polycyclic Aromatic Hydrocarbon
PHAST	Public Health Assessment Site Tool
PHS	Public Health Service
PID/FID	Photoionization detector/flame ionization detector
pCi/L	Picocurie per liter
PPRTV	Provisional Peer-Reviewed Toxicology Value
PQL	Practical Quantitation Limit
PRA	Paperwork Reduction Act
RL	Reporting Limit
RMEG	Reference Dose Media Evaluation Guide
RSL	Regional Screening Level
QA/QC	Quality Assurance/Quality Control
SAP	Sampling and Analysis Plan
SHOWER model	Shower and Household Water-use Exposure model
SSB	Science Support Branch
SMCL	Secondary Maximum Contaminant Level
SVOC	Semi-Volatile Organic Compound
THM	Trihalomethane
TPH	Total Petroleum Hydrocarbons
UL	Tolerable Upper Intake Limit
USPHS	United States Public Health Service
VOC	Volatile Organic Compound
WHO	World Health Organization

Executive Summary

Unconventional natural gas activities, such as hydraulic fracturing (fracking), have been ongoing in the Dimock, Pennsylvania area since 2008. Starting in 2011, the Agency for Toxic Substances and Disease Registry (ATSDR) alongside the U.S. Environmental Protection Agency (EPA), the Commonwealth of Pennsylvania, and other researchers have been working to assess the environmental and health effects of these activities in this area of northeastern Pennsylvania. After assessing environmental sampling data from 2009 to 2012, ATSDR determined in a 2016 health consultation that further sampling and analysis were necessary to accurately determine exposure and health risks within the community. To address this need, ATSDR performed additional sampling in a 2017 exposure investigation (EI) for some of the private wells sampled by EPA in 2012, as well as other household and drinking water sources. ATSDR also performed radon testing to address community concerns about the presence of and exposure to radon in indoor air. ATSDR developed and implemented an EI protocol (available upon request) that was specific to the Dimock community and their concerns. ATSDR presented the household and drinking water results and public health findings from the 2017 EI to participating Dimock residents in individual results letters sent to each participating residence in 2018. Homeowners were immediately notified of the results and provided with recommendations to reduce exposures when an acute exposure concern was identified (e.g., bacterial contamination, methane, or elevated radon levels). This report provides a public summary of ATSDR's overall public health findings in our 2017 EI regarding environmental exposures and public health impacts in this community.

For exposures as determined in the 2017 EI, ATSDR's conclusions are as follows (see Appendix D, Table D.5 for summarized estimated exposures and associated recommendations):

- Breathing trihalomethane vapor through household use at the maximum concentration detected in household water at HW01, HW02, HW06, HW12, and HW52 could harm residents' health.
- Drinking water that contains lithium, manganese, or copper at maximum concentrations at HW18, HW56, HW28, HW46, and HW49 for periods longer than a year may increase the risk for harmful noncancer health effects, especially in sensitive populations.
- Methane in drinking and household water sources above 10 mg/L at HW03 and HW25 could harm people's health due to ignition/explosive risks.
- Exposure to organic or inorganic contaminants from water use in homes not identified above, including private well water or alternative water sources, is not expected to harm residents' health. The levels of other contaminants in drinking/household water are below levels of health concern or water treatment systems effectively remove the contaminant to levels unlikely to harm people's health.
- Dimock residents who drink bottled water are not exposed to organic or inorganic contaminants found in their private wells or water sources. Because these residents drink bottled water and are not exposed to contaminants in their water, any contaminants found in their water are not expected to harm those people's health.
- Short-term radon testing showed radon in some homes at levels that could increase the risk for harmful health effects, including lung cancer. Radon detected in water is not expected to add appreciable radon to indoor air.

- Radiological contaminants in water samples from the Dimock area were found within acceptable levels.

The homes where ATSDR determined contaminants in water and/or air pose a public health concern are described in more detail in the "Discussion" section.

There are several limitations to this EI. The conclusions drawn from the sampling analyses only apply to the homes included in the EI during the period assessed. This assessment cannot be expanded to estimate specific exposures for the broader community. Further, some of the laboratory analytical detection limits were above ATSDR screening values, which creates uncertainty in the potential for harmful health effects from exposure to these contaminants.

ATSDR has included recommendations in this document to better characterize or reduce harmful exposures in the Dimock community. Residents are encouraged to monitor their water for any noticeable changes and to test their water regularly, as applicable. Where treatment is recommended for particular residences, ATSDR recommends installing, maintaining, and monitoring a system that reduces exposures to identified contaminants.

I. Purpose

The purpose of this health consultation document is to report on ATSDR's assessment of the potential health effects from exposures to contaminants detected in residential water sources and indoor air during the 2017 EI. Residents who participated in the 2017 EI received individual results and recommendations by June 2018. This report summarizes the overall findings, conclusions, and recommendations of the 2017 EI.

II. Background

Dimock, Susquehanna County, is a small rural and agricultural town in northeast Pennsylvania with approximately 130 homes and a population of 450 (U.S. Census 2010); demographic summary information can be found in Figure 1 in Appendix A. The 2017 EI included 25 homes containing 62 people; all of the participants were white. The participants' households were comprised of 14 children aged 17 years or younger (22%), 16 people older than 65 years (26%) and 8 women of child- bearing age (13%). Participants in 21 of the homes reported they had lived in the home more than 10 years; three participants have lived in their home for more than 1 and less than 10 years; one participant reported living in their home less than 1 year. In addition to the potential environmental impacts of hydraulic fracturing that has brought the area to the attention of the Environmental Protection Agency (EPA), residents in the community have expressed concerns for the potential health impacts related to exposures to chemicals released by natural gas drilling and processing activities.

To address these health concerns, ATSDR has been working with community and agency stakeholders. In 2011, ATSDR found that contaminant levels in these water supplies were at levels of health concern and recommended that residents avoid using water from these sources at that time (ATSDR 2012). ATSDR recommended appropriately operated and maintained alternative water treatment systems or bottled water for these select homes until the site could be further characterized. Since 2010, the natural gas drilling company, Cabot Corporation, has installed drinking water treatment systems in select homes. ATSDR is not aware of any environmental criteria that Cabot Corporation established to select homes for treatment. Four homes included in the EI continue to use a Cabot-installed treatment system on their groundwater wells, and one additional home has a Cabot-installed system, but that groundwater well is not in use. These water treatment systems, based on visual observation and anecdotal information provided by residents, have been designed to address methane gas contamination and other specific well water contaminants where regulatory guidelines, including EPA maximum contaminant levels (MCL) for public water systems and Pennsylvania Department of Environmental Protection (PADEP) medium-specific concentrations (MSC) for drinking water, are available. During ATSDR's field activities, two of the four residences with Cabot-installed water treatment systems noted that Cabot has decided to stop servicing their water treatment systems. ATSDR is unaware of the number of Dimock residences where Cabot Corporation installed a water treatment system.

After these 2011 findings were documented, ATSDR recommended that EPA further test the water. This drinking water testing was completed in 2012 for private wells at 64 residences that volunteered to be involved in the investigation. ATSDR issued a health consultation (HC) document in 2016 evaluating the data gleaned from this sampling event and found contaminant levels were not consistently at levels of health concern in the 64 private water wells. Of the residences where levels of contaminants created one or more acute health hazards (27 residences out of 64 had chemical contamination and 17 had physical hazards, i.e., explosivity), ATSDR recommended water treatment or replacement. As part of the conclusions in the ATSDR 2016 HC, additional sampling of Dimock private wells was recommended to characterize chronic exposures in the community. While PADEP and Cabot have continued monitoring select private Dimock residential well supplies, these data have not been consistently shared with ATSDR. The community's continued concern about changes in drinking water quality, variability in availability, operations and maintenance of treatment systems and/or alternative water supplies, and thus the overall health of their drinking water in the community, led to the ATSDR 2017 EI that is summarized in this document.

ATSDR's 2017 EI consisted of administering questionnaires to residents on their water usage, performing water sampling of raw and finished drinking water sources, and sampling for radon in indoor air. ATSDR collaborated with Pennsylvania Department of Environmental Protection (PA DEP), Pennsylvania Department of Health (PA DOH), EPA, and a third-party contractor to perform the EI.

In comparing 2012 and 2017 sampling data for only the untreated ground and spring water in the site area, most chemical-of-concern concentrations were consistent between the two data sets. However, some maximum contaminant concentrations were higher in 2017 (including barium, iron, and manganese). Natural gases were detected less frequently and at lower concentrations in the 2017 raw well samples. Further details of the comparison of 2012 and 2017 results can be found in Appendix G.

III. Methods

Selection Procedure

Of the 64 residences that had their water tested in 2012, ATSDR selected 25 homes to participate in the 2017 EI. ATSDR contacted or attempted to contact every residence that was sampled in 2012 to gauge interest in participating in the 2017 EI. Though many residents who were successfully reached were interested, ATSDR's selection was based on the residences with the highest concentration of contaminants or the largest number of contaminants exceeding screening values.

ATSDR tested all finished, first-draw tap water, raw private well water, alternative household water supplies held in storage tanks, and bulk water supplies (from the Montrose public water) stored in tanks at select residences. ATSDR gave questionnaires to all participating residents to better understand water usage in the home as well as basic demographic information. Residents received and signed consent forms before participating in the EI.

Environmental Media Collection

ATSDR and its contractor conducted field testing of indoor air and drinking water and collected samples for laboratory analyses. Field testing included air monitoring for total VOCs and airborne combustible gases, and water monitoring for conductivity, pH, temperature, and dissolved oxygen. Field samples were collected and sent to laboratories for contaminant-specific analyses.

Radon Testing

ATSDR placed short-term radon canisters in each home to test for indoor air radon concentrations in each home. One canister was placed in the primary living area, such as the kitchen, and a second was placed in the basement. For homes without a basement level, only one radon test kit was placed in the home. The canisters were placed in the home and collected 3 days later.

Health Assessment Evaluation Process

The primary exposure assessed was ingestion of private well drinking water, but inhalation and dermal absorption were also assessed. Because some Dimock residents may use multiple sources of water, such as ponds, springs, and delivered bulk water for household uses and/or drinking water, ATSDR incorporated these water supplies into the health assessment analysis. Complete exposure pathways were for residents' current water uses at the time of the EI. For example, a resident who drinks untreated well water would have a completed exposure pathway for ingestion of their well water. For some homes, residents may choose bottled or alternative water sources for drinking. To better assess the overall water quality (independent of the arrangements they had during the EI), we evaluated these sources as "potential" pathways. Some homes that had either point-of-use (POU) or whole-house treatment systems for drinking water. Raw (untreated) water is considered an "incomplete" pathway because residents are not exposed to contaminants in raw water due to the water treatment system removing these contaminants.

Analytical results of the 2017 ATSDR EI were compared to appropriate screening levels, primarily ATSDR health-based comparison values (CV), to identify contaminants of concern (COCs). We used the maximum concentration detected for each contaminant as the Exposure Point Concentration (EPC), and this EPC was used to screen the contaminants for further evaluation. Screening levels from other federal and state programs (Department of Interior [DOI], EPA, California EPA) and the World Health Organization (WHO) were used when ATSDR CVs were not available. If the concentration of a contaminant is below the screening level, harmful effects are unlikely to occur. If the concentration of a contaminant is above the screening level, or if there is no screening value available, ATSDR further evaluates exposure to the contaminant to determine if adverse health effects may occur.

ATSDR used its Public Health Assessment Site Tool (PHAST) to screen each contaminant found in the water samples to identify Contaminants of Concern (COCs). A list of the screening levels used, including ATSDR CVs and non-ATSDR values, are provided in Appendix C. The COCs identified from the screening process were evaluated for ingestion exposure to assess drinking source water if the water source was used for drinking water. Volatile organic compounds (VOCs) that were identified as COCs were also evaluated for inhalation and dermal exposure if the water source was used for household use. In homes where an alternative source of drinking water was used, such as bottled water, volatile organic compounds (VOCs) in household water supplies were evaluated for inhalation and dermal exposures only.

After determining COCs, ATSDR used PHAST to calculate ingestion exposure doses and the corresponding noncancer hazard quotients (HQs) and cancer risks by comparing the dose to appropriate health guidelines. The HQ for a chemical is the ratio of the estimated exposure dose to the ATSDR minimal risk level (MRL), EPA reference dose (RfD), or other health guidance value. MRLs are derived from data in epidemiologic and toxicologic literature and include uncertainty factors and indicate whether further evaluation is necessary. Any contaminant that had an HQ equal or over 1.0 was further evaluated for risks of adverse health effects. If the HQ is less than 1.0, noncancerous harmful effects are unlikely to occur. ATSDR assessed both noncancer health evaluations and cancer risks for each COC. For the cancer assessment, cancer risks associated with each contaminant were calculated and summed when applicable. This process is described in detail in Appendix C. Inhalation and dermal exposure were calculated for chemicals that readily volatilize using ATSDR's Shower and Household Water-use Exposure (SHOWER) model using household-specific scenarios (ATSDR 2020). Because some contaminants such as metals and major ions do not readily volatilize or absorb through the skin, ATSDR did not evaluate inhalation and dermal exposure to these contaminants using the SHOWER model. Further information on the SHOWER model results is presented in Appendix D.

Ingestion and inhalation screening levels and hazard quotients are determined for specific exposure durations, which include acute durations, where exposures may occur for up to 2 weeks; intermediate exposures, where exposures may occur for more than 2 weeks but less than 1 year; and chronic exposures, where exposures occur for more than 1 year and up to a lifetime. Cancer risks are calculated for chronic exposure only. Health implications from exposures to COCs identified in Dimock water sources are further evaluated in the Discussion section.

IV. Results

Tables 1 and 2 provide a list of COCs in all water sources and the number of samples that exceeded the applicable CVs. Contaminants that exceeded available CVs were quantitatively evaluated using PHAST and the SHOWER model, as appropriate, and those without available CVs were qualitatively evaluated. ATSDR performed a screening for each water sample at each location to evaluate potential exposure to residents within the household. Appendix C provides a listing of the screening values used to evaluate the data. The value used to screen the data is the same value that was used in the quantitative evaluation since only one sample is available.

ATSDR included chronic (greater than 1 year) exposure doses in addition to acute and intermediate because residents' answer to the questionnaire indicated long-term residency.

ATSDR used "first-draw" water samples to compare to screening values and to calculate doses. First-draw water samples were taken without purging the tap first. These samples can often show higher concentrations of some contaminants that become diluted after the water is run. As such, these results were used as a worst-case scenario. Contaminant concentration may be lower in "flush" samples, where water is allowed to run for several minutes before collecting the sample.

Some residents use one water supply for household use and another water supply for drinking water and cooking. Household use of water includes showering, bathing, and handwashing and during the use of appliances such as the dishwasher and clothes washer. Raw water and alternative water supplies were used for household use only and not as a source of drinking water. As such, exposure to these water sources is primarily by dermal and inhalation pathways during household use.

Ingestion exposure to contaminants in the water supply were evaluated using PHAST for first-draw water samples. For those contaminants that may volatilize into the air during household use of water, the SHOWER model was used to evaluate inhalation and dermal contact. For some water sources that are not used for drinking water, we still evaluated the ingestion pathway (see Appendix C) as a potential pathway. It is important to note that the categorization of exposure pathways as complete, incomplete, potential, or eliminated is based on the 2017 EI survey. If water use patterns and behaviors change since the survey was conducted in 2017, the exposure pathways may change status to complete and thus expose residents to contaminants in their well or spring.

The results of the quantitative analysis of COCs using both PHAST and the SHOWER model for each household that meets or exceeds an HQ of 1.0 and/or an excess lifetime cancer risk (ELCR) of 1E-06 (one additional cancer per million people exposed) are provided in Appendix D and evaluated further for noncancer or cancer health effects. Note that ELCRs are a theoretical estimate of cancer risk that ATSDR uses as a tool for deciding whether public health actions are needed to protect health; they are not actual estimates of cancer cases in the community. Tables are provided below for each class of contaminants, the number of water sources that exceeded screening values, and the maximum concentration detected.

Table 1. Contaminants Exceeding Screening Values

Contaminant	Comparison Value (CV) in µg/L	CV Source*	# of Detections Above CV	Maximum Concentration Detected (µg/L)
Bromodichloromethane	0.39	CREG	7	13
Chlorodibromomethane	0.29	CREG	5	1
Chloroform	70	Child cEMEG & RMEG	3	670
Bis(2-ethylhexyl)phthalate	0.7	Child iEMEG	1	3.5
1,2-Dibromoethane	0.012	CREG	1	0.68
Carbon tetrachloride	0.35	CREG	2	0.57
Vinyl chloride	0.017	CREG	2	0.32
Methane	10,000	DOI	7	15,000
Arsenic	0.016	CREG	9	91
Barium	1400	Child cEMEG & RMEG	6	5,300
Copper	70	Child iEMEG	6	360
Fluoride	350	Child cEMEG (for sodium fluoride)	5	2,400
Iron	300	EPA SMCL	11	6,400
Lead	15	EPA action level	2	72
Lithium	40	Child RSL	10	300
Manganese	430	Child RSL (not diet)	3	1,200
Sodium	20,000	EPA DWL	20	99,000

Uranium (metal)	1.4	Child iEMEG (uranium soluble salts)	14	6.5

µg/L = micrograms contaminant per liter drinking water;
*Comparison value (CV) type: CREG = cancer risk evaluation guide; EMEG = environmental media evaluation guide; cEMEG = chronic environmental media evaluation guide iEMEG = intermediate Environmental Media Evaluation Guide; RMEG = reference dose media evaluation guide; RSL = EPA's regional screening level; DOI = Department of the Interior (CV for methane); MCL = EPA maximum contaminant level, SMCL = secondary maximum contaminant level; Manganese RSL refers to non-food sources of manganese in the diet.

Table 2. Contaminants Evaluated with No CVs Available

Contaminant	Number of Detections	Maximum Concentration Detected (µg/L)
2-chloroethyl vinyl ether	1	24
Butane	7	1.2
Ethane	11	430
Propane	3	8.2
Gasoline range organics (GRO) (C6-C10)	3	170
Diesel range organics (DRO) (C10-C28)	3	470
Hexane extractable materials (HEM - Oil & Grease)	5	17,600

Note: Several elements (bromide, chloride, sulfate, titanium) and essential nutrients (calcium, magnesium, potassium) were also detected in water supplies, but appropriate health-based screening levels are not readily available.

V. Discussion

The COCs identified in the previous section were further evaluated to determine whether health effects may occur from ingestion, inhalation, or dermal exposure. ATSDR was mindful of where water treatment was installed or if alternative supplies were used as the primary drinking water source in a home. ATSDR compared raw and treated water contaminant concentrations when both samples were collected. Unless residents indicated they used bottled water as their primary drinking water source, first-draw samples from the residence's primary tap were considered for ingestion exposures, regardless of whether water treatment was installed. There were seven wells where residents had exposures to COCs in their primary drinking water source; all other water sources assessed were evaluated for potential exposure only. For residents who had alternative drinking water arrangements, ATSDR evaluated some of those water sources for ingestion exposure to assess overall water quality at each residence. This additional information is provided to help residents understand the potential risks associated with drinking their household water.

ATSDR informed participants of their water sampling results by mail and/or email and with follow-up phone calls. When an acute exposure concern was identified (e.g., bacterial contamination, methane, or elevated radon levels), homeowners were immediately notified of the results and provided with recommendations to reduce exposures. Individual letters were sent to each participant providing contaminant concentrations and ATSDR's evaluation of the potential health implications of their household's specific exposures to those contaminants. The letters addressed individual household and drinking water supplies and focused on first-draw tap water samples.

Chemicals and products associated with natural gas production are not normally found in drinking water and were targeted for assessment as part of the EI. This EI, while focusing on follow up to the 2012 EPA sampling for contaminants associated with natural gas drilling activities in the area, assessed any contaminants found in residences' water supplies that may adversely impact human health. However, the presence of organic compounds and other contaminants in groundwater or surface water can come from many sources. Further, some naturally occurring salts and metals may be mobilized in an aquifer due to the geochemical effects of natural gas drilling and hydraulic fracturing. Environmental regulators, and not ATSDR, are responsible for identifying sources of contaminants and the environmental fate and transport of those contaminants.

Public Health Impacts of Potential and Completed Exposures

A. Organic Chemicals

Organic Chemicals other than trihalomethanes

With the exception of one residence (HW01), organic chemicals were not consistently detected in the water supplies in the Dimock community. Organic chemicals that were detected above screening values or for which screening values are not available were bis(2-ethylhexyl) phthalate, vinyl chloride, 1,2-dibromoethane, and 2-chloroethyl vinyl ether.

Two of the contaminants, 1,2-dibromoethane and vinyl chloride, were detected above screening values in raw (untreated) drinking water. One organic chemical that was detected did not have a screening value, 2-chloroethyl vinyl ether. These contaminants were both detected in chlorine-treated pond water stored in holding tank. Residents described this water as household-use only, and dermal and inhalation exposures are the only completed pathways for this water source. ATSDR also assessed ingestion as a potential pathway, should the residents decide to drink the water in the future (see Appendix C for organic chemicals ingestion pathways). Because these contaminants readily volatilize into the air, ATSDR used its SHOWER model to estimate concentrations in indoor air within the home.

Two organic chemicals were detected in source water above screening values at this location – bis(2-ethylhexyl) phthalate and vinyl chloride. Dermal and inhalation exposure was assessed for vinyl chloride and for bis(2-ethylhexyl) phthalate in the SHOWER model. See Appendix D for specific hazard quotients and cancer risk information.

Bis(2-ethylhexyl) phthalate (DEHP)

Bis(2-ethylhexyl) phthalate (di(2-ethylhexyl) phthalate or DEHP) was detected at 0.0035 milligrams per liter water (mg/L) in the HW01's chlorine-treated pond water stored in a holding tank (see Appendix B for complete sample descriptions). Though the residents affirmed to ATSDR during the EI that they do not drink this water, the concentration of DEHP detected exceeds ATSDR's health-based Comparison Value, or CV, of 0.0007 mg/L (ATSDR intermediate Environmental Media Evaluation Guide, or iEMEG) and was evaluated for oral exposure in PHAST (see Appendix C) and inhalation and dermal exposure in the SHOWER model. The value of 0.0035 mg/L is also above the Cancer Risk Evaluation Guide or CREG of 0.0017 mg/L.

Though there is no chronic MRL available, DEHP has an intermediate MRL of 0.0001 mg/kg/day. PHAST uses the intermediate EMEG (derived using the intermediate MRL) to screen the data and to derive the HQ. The intermediate MRL of 0.0001 mg/kg/day is based on a study from 2015 that reported developmental effects in a subchronic study in mice (Zhang et. al., 2015). PHAST determines a maximum dose for a reasonable maximum exposure (RME) of 0.0005 mg/kg/day for infants younger than 1 year old. Though the RME dose is associated with an HQ of 5.0 for infants younger than 1 year old, this dose is far below the study's lowest observed adverse effect level (LOAEL) of 0.04 mg/kg/day. Harmful developmental effects from ingestion of DEHP in drinking HW01 water are unlikely. The SHOWER model predicted an exposure dose from dermal exposure of 0.008 mg/kg/day, which is above the intermediate MRL of 0.0001 mg/kg/day. However, this dose is well below the LOAEL identified in the Zhang et. al. study and is unlikely to cause harmful health effects.

The ELCR was 4E-05 for dermal exposure, which is four additional cancers among 100,000 persons exposed, which causes some concern for increased cancer risk. This increased risk is more of a concern than drinking water that only had DEHP present, because HW01 has other cancer-causing chemicals (carcinogens) present. The chronic HQ for inhalation and dermal exposure pathways did not exceed one. The SHOWER model did not estimate doses for inhalation exposures to DEHP due to DEHP's low likelihood to volatilize. Dermal doses did not result in hazard quotients above 1 (see Appendix D for specific doses).

Completed Pathway Hazard Determination: ATSDR concludes that inhalation and dermal exposures to DEHP in source water at HW01 are not a health concern for noncancer effects but contributes to a concern for increased cancer risk due to the cumulative effect of other carcinogenic contaminants in this water source.

Vinyl chloride

Vinyl chloride was detected in HW01 (chlorine-treated pond water stored in a holding tank) at 0.00032 mg/L. This level exceeds ATSDR's health-based CV of 0.000017 mg/L (CREG) and was evaluated for oral exposure in PHAST (see Appendix D) and inhalation and dermal exposure in the SHOWER model. The ELCR was 9E-06 for oral exposure, which is 9 additional cancers among 1,000,000 persons exposed. As with DEHP, this low level increase in cancer risk contributes to a concern for cancer risk due to the presence of multiple carcinogens in this water source. SHOWER model inhalation and dermal doses did not result in a chronic HQ over 1. However, the detected value is a laboratory estimated value, which indicates uncertainty in the detected value.

Completed Pathway Hazard Determination: Despite the laboratory estimated value for vinyl chloride creating uncertainty in the actual exposure at HW01, ATSDR concludes that inhalation and dermal exposures to vinyl chloride in source water at HW01 are not a health concern for noncancer health effects.

1,2-Dibromoethane (EDB)

1,2-Dibromomethane (EDB) was detected in HW01 water at 0.00068 mg/L. This level exceeds ATSDR's health-based CV of 0.000012 mg/L (CREG) and was evaluated for inhalation and dermal exposure in the SHOWER model.

ELCR from inhalation exposure at the modeled EDB level is 4E-05, or 4 additional cancers among 100,000 persons exposed. Because of the presence of DEHP and vinyl chloride, this level causes concern for increased cancer risk. The chronic HQ did not exceed one for inhalation and dermal exposure; therefore, noncancer effects from EDB inhalation exposures in this home are also not expected. In addition, the detected value is a laboratory estimated value, which indicates uncertainty in the detected value.

Completed Pathway Hazard Determination: ATSDR concludes that inhalation and dermal exposures to EDB in raw water at HW01 are not a health concern for noncancer health effects but contribute to a concern for increased cancer risk.

2-Chloroethyl Vinyl Ether

2-Chloroethyl vinyl ether was detected at 0.024 mg/L in the HW01 sample, so ATSDR assessed dermal and inhalation exposure via the SHOWER model. There are no health-based screening levels available from ATSDR or EPA to assess exposures to this chemical in indoor air or by dermal exposure. The Michigan Department of Environmental Quality has identified a target concentration, not a health-based value, of 0.010 mg/L in water for further evaluation (MDEQ 2015).

The National Library of Medicine (NLM) classifies 2-chloroethyl vinyl ether as an irritant (NLM 2003). Irritants cause inflammation and swelling with local tissue irritation, which can lead to rhinorrhea, cough, shortness of breath, bronchospasm, irritation of oral mucous membranes and esophagus, and rarely upper airway swelling or acute lung injury. Because the contaminated water supply is used for showering and bathing, dermal exposures to this irritant may occur. Although there is limited information regarding dermal exposures, in one animal study, researchers found dermal exposure to pure 2-chloroethyl vinyl ether did not cause even slight erythema, or redness of the exposed skin. Exposure at Dimock residences would be to a very diluted amount of the chemical in the water. Since the pure chemical did not cause skin irritation, a much smaller amount found in household water would be unlikely to cause adverse skin effects. The NLM noted that eye irritation has been reported following exposures to this chemical; however, more specific information regarding dose levels and response from human exposures is not available for this irritant (NLM 2003).

Completed Pathway Hazard Determination: Based on the limited literature regarding health effects from exposure, ATSDR concludes that skin irritation from exposure to this chemical at HW01 is unlikely. There is not enough information to know whether exposure may result in other effects.

Trihalomethanes (THMs)

Trihalomethanes (THMs) were found at different levels in multiple water sources in Dimock. A byproduct of using chlorine as a disinfectant, THMs are a class of chemical can cause adverse health effects at high levels. EPA regulates total THMs to 80 µg/L which is a cumulative number that accounts for multiple THM chemicals. The MCL for THMs is based on potential effects on the liver, kidneys, and central nervous system, as well as increases in cancer risk from ingesting the water (EPA 2019a). While THM levels were found below the MCL at some residences, two residences, HW01 and HW06, exceeded the MCL for THMs. However, both HW01 and HW06 use bottled water for drinking and do not consume the water that was assessed in this EI. Chloroform, bromodichloromethane, and chlorodibromomethane were detected above screening levels; all other detected THMs were found below screening levels. ATSDR used the concentrations detected in Dimock water sources to calculate exposure doses for each THM in each residence. Tables in Appendix D include RME doses, which are considered as the uppermost estimated exposure level possible based on the data set available. All households with THM detections above screening levels were 2-person households except for HW06, which was a 5-person household. Inhalation and dermal exposure through household use is proportional to household size because water use increases (and thus creates more chemical vapor) with the number of people using water in a home. For raw and bulk water data, only the inhalation and dermal pathways were evaluated using the SHOWER model. The results of potential oral exposure associated with the raw water data exposure are provided in Appendix D for informational purposes.

Residents in homes with THM contamination in their water supply, including those homes where the contaminated water is not consumed, will be exposed by inhalation and dermal pathways from household use of THM-contaminated water. Chloroform, at low concentrations, was detected in some household water samples that are not treated with chlorine. Exposures (inhalation and dermal) to chloroform in these homes are also assessed in this section.

The SHOWER model was run for the maximum detected concentration of three THMs that exceeded the screening levels at the following homes: HW01, HW02, HW06, HW12, and HW52. The estimated resultant air concentrations and dermal exposure doses were compared to appropriate health guidelines to derive a HQ and a cancer risk for each THM component.

Specific exposure point concentrations (EPCs), HQs, and cancer risks can be found in Appendix D. For each residence, the EPC was the maximum concentration detected at the residence for the COC. HQs did not exceed 1.0 for any completed pathway at any residence; therefore, noncancer health effects from exposure to THMs in water are unlikely. Exposure to THMs result in ELCRs greater than 1E-06 for inhalation and/or dermal exposure at HW01, HW06, HW12 and HW52 for the first-draw data, primarily resulting from exposure to chloroform. Increased cancer risks were of particular concern at HW01 and HW06, where ELCR were 1E-03 at both residences. Similar results were found for inhalation and/or dermal exposure to the raw (HW01) and bulk (HW02 and HW52) water samples. As indicated above, these contaminants are not due to hydraulic fracturing and are the result of water treatment practices.

Potential Pathway Hazard Determination: Though these homes use bottled water, potential inhalation and dermal exposure to THMs through household use in HW01, HW06, and HW12 causes concern for increased cancer risk. Potential exposure to THMs in HW52 water poses a low increased cancer risk, while potential exposure to THMs in HW02 water poses an insignificant risk.

B. Natural Gases

Natural gases, including methane, ethane, propane, and butane, were detected in Dimock residential water supplies sampled during the 2017 ATSDR EI. The presence of these natural gases in residential water supplies is a safety hazard due to their flammability. For methane in water, the U.S. Department of Interior (DOI) identified a cautionary level of 10 mg/L for residents and a level of 28 mg/L as a concentration above which immediate steps are recommended to reduce the risk of explosion or fire within the home (DOI 2001). Some Dimock homes raw water contained methane above the cautionary level of 10 mg/L but less than the level where immediate steps are needed. Some homes are monitored by Cabot Corp. and/or PADEP or may also have treatment to lessen methane concentrations before entering the home's plumbing system. Table 3 summarizes the natural gas detections in tap and groundwater in the 2017 ATSDR EI.

Table 3. Natural Gas Detections in Tap and Groundwater

Location	1st Draw Methane (mg/L)	1st Draw Source	Does well contain ethane, butane, or propane?	Well Methane (mg/L)
HW01	0.0036	Pond	No	NA
HW02	ND	Bulk	Yes	3.1
HW03	**11**	**Well**	Yes	**12**
HW06	ND	Creek	Yes	**13**
HW12	0.065	Spring	Yes	**13**
HW14	ND	Well	Yes	ND
HW17	1.6	Well	Yes	1.2
HW18	0.34	Well	No	0.34
HW25	**15**	**Well**	**Yes**	**11**
HW32	0.083	Well	No	0.091
HW36N	ND	Well	No	0.008
HW39*	0.0026	Well	Yes	6.8
HW47	ND	Well	No	5.2
HW48	0.0012	Well	No	ND
HW52	0.93	Bulk	Yes	**11**
HW56	8.3	Well	Yes	7.7
HW63	ND	Well	No	NA

Notes: results in milligrams per liter (mg/L); ND = not detected above method detection limit; NS = Not Sampled; 1st draw = sample collected from unpurged resident tap after water treatment, if any; **bold** indicates a methane exceedance of the cautionary level of 10 mg/L; NA =- not available

The primary concern regarding the presence of natural gas in household water is the potential for creating explosive/flammable atmospheres inside dwellings when those gases are released from turning on the tap water. At very high levels, natural gas has the potential to displace air in enclosed poorly ventilated spaces and could become an asphyxiation hazard. Concentrations of natural gases detected in the water in the 2017 EI are not expected to buildup in indoor air to levels where asphyxiation becomes a concern. **As stated in letters to each residence after the EI, ATSDR recommends that residences where concentrations of methane in well water exceeded 10 mg/L, homeowners should install a vent on their wellhead, treat water to remove methane, install a combustible gas meter in the home, and continue to test water for natural gases.**

The methane, propane, and butane that were detected in some homes' wells are not regulated nor have any screening values to assess their potential health risks. Their presence contributes to the cumulative effect of natural gas in the home and can increase the risk of fire or explosion. The presence of some of these natural gases may aid in identifying the source of natural gas in some Dimock residential wells. The distribution and type of natural gases among Dimock homes can indicate which drilling processes contribute to the presence of natural gas in drinking water

(Osborn and McIntosh 2010). However, source identification of natural gases in the home is beyond the scope of ATSDR's mandated authorities.

C. Metals and Major Ions

Several metals and major ions were detected in Dimock water supplies, though there were no consistent trends throughout the sample pool. It is also unclear whether these contaminants are due to natural gas drilling or hydraulic fracturing or if they are naturally occurring due to local geochemistry. Further, sources of exposure to some contaminants have been reduced or eliminated due to current practices for those applicable residences. For example, the maximum concentrations of some inorganic contaminants were identified in water supplies not used for drinking water. Effective treatment or the use of an alternative water supply has also removed or eliminated exposure to inorganic contaminants. See Appendix D for specific exposure point concentrations, hazard quotients, and cancer risks.

Arsenic

Arsenic is a naturally occurring metal in groundwater. The ATSDR Toxicological Profile for Arsenic indicates that drinking water generally contains an average of 0.002 mg/L of arsenic, although higher levels may occur near natural mineral deposits or anthropogenic (man-made) sources (ATSDR 2007a). Arsenic was detected in multiple water sources in Dimock. Levels in first-draw water were present at concentrations from 0.0066 to 0.0085 mg/L, resulting in derived HQs ranging from 3 to 4 and ELCRs of 2E-04 (two additional cancer cases in 10,000 exposed individuals). Though residents at these homes do not drink their well water, ATSDR determined the potential health risks associated with ingestion. The maximum concentration of arsenic detected in first-draw water (0.0085 mg/L at HW12) was associated with a RME dose of 0.0012 mg/kg-day for infants younger than 1 year old, which exceeds the ATSDR arsenic chronic MRL of 0.0003 mg/kg-day. The chronic MRL for arsenic is based on a study that found skin lesions in people exposed to various levels of arsenic in their drinking water over a long period. However, ATSDR determined that the dermal studies indicate a threshold dose for these skin effects of 0.002 mg/kg-day. Because the maximum dose is below this threshold, ATSDR would not expect noncancer adverse skin effects from exposure to arsenic in drinking water. Though a maximum value found in all sources tested was 0.091 mg/L was detected in one raw water sample, residents are not drinking the raw water at this residence. Residents should continue to maintain their treatment system to avoid the potential for arsenic exposure at levels that can cause adverse health effects.

It is important to note that the arsenic laboratory detection limit of 0.004 mg/L is above the ATSDR ingestion CREG of 0.000016 mg/L. Therefore, it is unknown whether some water supplies had arsenic concentrations above the ingestion CREG but below the detection limit. Given the uncertainty of the presence of arsenic at levels below the laboratory detection limit of 0.004 mg/L, ATSDR calculated the theoretical ELCR from exposures to arsenic at the laboratory detection limit. The ECLR of 1E-04 estimates one additional cancer risk in 10,000 exposed individuals, which is a concern for increased cancer risk if the residents resume drinking the water.

Arsenic is classified as a human carcinogen. This classification is based on animal and human studies that indicate an increased risk for developing cancers of the skin, lung, bladder, kidney, liver, and prostate from consuming arsenic-containing water. A key parameter in estimating cancer risk is the EPA cancer slope factor, which was derived from arsenic exposures via drinking water and skin cancer cases reported in a Taiwanese study (ATSDR 2007a).

Potential pathway hazard determination: Exposure to arsenic in drinking water at the maximum dose is unlikely to cause noncancer adverse health effects but may increase the risk for cancer health effects. Should residents switch from bottled water to well water, treatment systems should be installed and maintained to allow for removal of arsenic from the drinking water where levels exceed health-based screening values.

Barium

Barium was reported in several water samples in Dimock at levels ranging from 1.6 to 5.3 mg/L, with associated HQs from 3 to 4 (no ELCR since barium is not carcinogenic). The maximum barium concentration at one residence of 5.3 mg/L was detected from a raw water source, with the potential for exposure if the treatment system currently in place is removed or not maintained properly.

Barium is a naturally occurring metal in groundwater. The ATSDR Toxicological Profile indicates that drinking water generally contains an average of 0.030 mg/L of barium but can average as high as 0.302 mg/L (ATSDR 2007b). Natural background levels of barium specific to the Dimock area are not available, but it appears that levels may be above natural background.

Health effects associated with barium include hypokalemia (low potassium levels) which can result in tachycardia (rapid heartbeat), effects on blood pressure, muscle weakness, and paralysis (ATSDR 2007c). Barium displaces potassium channels in the blood and, therefore, results in effects associated with low potassium. Based on animal studies, there is evidence that most sensitive adverse effect of barium is kidney toxicity with length of exposure being important in toxicity.

The chronic MRL of 0.2 mg/kg/day is based on the BMDL05 (the 95% lower confidence limit on the benchmark dose) of 61.13 mg/kg/day (applying an uncertainty factor of 300: 10 to account for animal to human extrapolation, 10 to account for human variability, and a modifying factor of 3) for nephropathy (ATSDR 2007c). The exposure doses derived for barium in the first-draw Dimock water samples that exceeded CVs ranged from 0.23 to 0.76 mg/kg/day, which is comparable to the MRL but well below the BMDL05 for effects on the kidney (ATSDR 2007c).

Completed pathway exposure determination: ATSDR concludes that estimated barium exposures from the assessed Dimock drinking water samples are not expected to result in adverse health effects.

Copper

Copper was reported in first-draw water at levels ranging from 0.14 to 0.36 mg/L, resulting in derived intermediate HQs ranging from 2 to 5. Neither a chronic MRL nor an RfD are available, so a chronic HQ was not derived. EPA does not classify copper as a human carcinogen because there are no adequate human or animal cancer studies (ATSDR 2004); therefore, an ELCR was not derived. In raw and bulk water, levels greater than the CV ranged from 0.12 to 0.22 mg/L (with associated HQ range of 2 to 3).

Three drinking water samples had copper detections above the ATSDR screening value of 0.070 mg/L; however, two of these samples also had low levels of laboratory blank contamination (less than 0.001 mg/L), qualifying the concentrations reported in the results as uncertain. Based on the laboratory analyses, ATSDR assumes copper is present in each of the three drinking water supplies at levels exceeding the screening value of 0.070 mg/L. The copper concentrations detected in these three drinking water samples are below the EPA action level for enhanced water quality monitoring for public water supplies (1 mg/L).

Copper is essential for good health. However, exposure to high doses can be harmful. The greatest potential source of exposure to copper is from contaminated drinking water, especially in water that is first drawn in the morning after sitting overnight in plumbing composed of copper piping and brass faucets (ATSDR 2004). Drinking water that contains higher than normal levels of copper may result in nausea, vomiting, stomach cramps, or diarrhea.

ATSDR has not developed a chronic MRL for copper, but PHAST uses an intermediate MRL to derive intermediate HQs of 2 to 5, which are above 1. In identifying the intermediate-duration MRL of 0.01 mg/kg/day, ATSDR used a study in humans which identified a NOAEL of 0.042 mg/kg/day and a LOAEL of 0.091 mg/kg/day for gastrointestinal effects (ATSDR 2004). Doses associated with the first-draw water samples that exceeded the CV ranged from 0.02 to 0.05 mg/kg/day which is comparable to the NOAEL to LOAEL range used as the basis of the intermediate MRL.

The acute MRL study identified a NOAEL of 0.027 mg/kg-day and a LOAEL of 0.073 mg/kg-day. However, there are numerous human studies showing that a one-time exposure to 0.011 to 0.018 mg/kg exposure will cause gastrointestinal effects (i.e., nausea, abdominal pain, and vomiting). Both intermediate and acute exposure to concentrations of copper found in the Dimock area may cause adverse health effects, such as gastrointestinal upset.

Completed pathway hazard determination: Copper exposure in Dimock area drinking water may cause acute (short-term) or longer term gastrointestinal effects, especially for children.

Fluoride

Fluoride was found in two drinking water tap samples at concentrations ranging from 0.78 to 2.4 mg/L, which exceed ATSDR's chronic EMEG of 0.35 mg/L for sodium fluoride. Raw and bulk water samples also exceeded the CV with concentrations in water ranging from 0.79 to 0.89 mg/L.

Fluoride is a naturally occurring mineral added to public water supplies for prevention of dental decay. Since 1962, the United States Public Health Service (USPHS) has recommended that public water supplies contain between 0.7 and 1.2 mg/L fluoride for the prevention of dental decay (ATSDR 2003). The Pennsylvania American Water-Montrose public water provider adds fluoride to their water supply to maintain a fluoride concentration near 0.7 mg/L (PAM 2016). The concentrations found in the first-draw water samples are comparable to the recommendations from the USPHS.

The EPA has set a maximum contaminant level (MCL) of fluoride allowable in drinking water of 4.0 mg/L (EPA 2019a). In adults, exposure to fluoride can result in denser bones. However, if exposure is high enough, these bones may become more fragile and brittle, and there may be a greater risk of breaking.

A chronic MRL of 0.05 mg/kg/day for sodium fluoride was used by PHAST to derive HQs greater than one (range 2.2 to 6.8). The MRL is based on a NOAEL of 0.15 mg/kg/day for increases in bone fractures in older adults (uncertainty factor of 3 to account for human variability) in a human study

(ATSDR 2003). Because this study is based on bone fractures in older adults whose bones may be more brittle due to age, the effects may not be observed in children. The RME dose for adults was 0.093 mg/kg-day, which does not exceed the NOAEL. ATSDR does not expect an increased risk of bone fractures in adults due to exposure to fluoride in drinking water.

Sample HW02-F was collected from a kitchen tap with a treatment system and the water is from the Montrose public water supply. The concentration detected in HW02-F drinking water falls within the USPHS recommended level for fluoride in drinking water and is not expected to cause adverse health effects. Raw (HW06) and bulk (HW02, HW52) water samples also fall within the USPHS recommended level if these water sources are used as a drinking water source.

The fluoride level detected in HW63-F (2.4 mg/L) is above the level recommended by the USPHS for public water supplies, but below the MCL of 4 mg/L. Residents at HW63 and HW21 do not use their tap water as their *primary* water supply. Occasional fluoride exposures from these water supplies are not expected to increase the risk of adverse health effects.

Completed pathway hazard determination: Based on the exposure scenarios and detected concentrations in all Dimock water supplies sampled, adverse health effects from exposure to fluoride are not expected.

Manganese

Two first-draw water samples had manganese detected above the CV, with a maximum value of 0.62 mg/L. Though HW12 exceeded the CV, the residents at this home drink bottled water instead of their tap water. HW56 was the only residence where manganese was present in finished drinking water above the screening level. Other water sources, including spring, bulk, or alternate sources, did not have manganese detected in the 2017 EI.

ATSDR's MRL for manganese is associated with the inhalation pathway; there is no MRL for the oral pathway. Without an oral MRL, ATSDR used the EPA manganese long-term health advisory (LTHA) level of 0.3 mg/L to screen manganese concentrations in water (EPA 2012). Further, ATSDR used the scientific literature to identify a LOAEL of 0.07 mg/kg/day to compare with the estimated exposure doses for manganese in drinking water (ATSDR 2012). We then used this information to generate a summary table of protective public health recommendations for private well water users (Table 4). ATSDR calculated exposure doses for several age groups (infants, children, adults) to develop these recommendations using age-specific maximum intake assumptions. The three studies investigating manganese exposure in children with neurological endpoints had estimated LOAELs ranging from 0.06 to 0.08 mg/kg/day. ATSDR selected the mid-range LOAEL to use in this evaluation. Based on our evaluation of the available sampling information for private wells from this site area, ATSDR concludes that there may be neurological health concerns for infants and children regularly consuming water with elevated levels of manganese.

Table 4. Protective public health recommendations related to manganese for private well water users

Manganese (ug/L)	Recommendation
0.300 mg/L or less	Routine private water well monitoring, including analyses for manganese.
0.3 mg/L to 0.5 mg/L	Infants (birth to 1 year) use bottled water or use appropriate and properly maintained water treatment system with bi-annual water quality monitoring.
>0.5 mg/L	Infants and children use bottled water or use appropriate and properly maintained water treatment system with bi-annual water quality monitoring.
>1 mg/L	All age groups use bottled water or appropriate and properly maintained water treatment system with bi-annual water quality monitoring.

Completed pathway hazard determination: Exposure to manganese in drinking water at HW56 may result in neurological health effects for infants and children.

Uranium

Seven households had uranium concentrations above the CV of 0.0014 mg/L for uranium (soluble salts); five in first-draw samples (range of 0.0014 to 0.0065 mg/L) and seven in raw water (range of 0.0018 to 0.0063 mg/L). Uranium was not detected in spring, bulk or alternate source samples during the 2017 ATSDR EI.

EPA provides a RfD of 0.003 mg/kg/day for uranium (soluble salts). ATSDR does not provide a chronic MRL but does report an intermediate MRL of 0.0002 mg/kg/day, which is considerably lower than the RfD (ATSDR 2013). PHAST uses an intermediate EMEG (0.0014 mg/L for children) based on the intermediate MRL to screen uranium data. Similarly, PHAST uses the intermediate MRL to calculate a chronic HQ because it provides a more conservative estimate than using the RfD.

All but one source of water (including raw and first-draw samples) had HQs at or below one. The HW17 water supply (raw and first-draw) had HQs of 5.

The intermediate MRL of 0.0002 mg/kg/day is based on effects on the kidneys in children (ATSDR 2013). The intermediate MRL uses a LOAEL of 0.06 mg/kg/day for renal effects in rats (uncertainty factor of 300: 3 for use of a minimal LOAEL, 10 for animals to human extrapolation, and 10 for human variability). ATSDR determined that the data available for chronic exposure was not robust enough to derive a chronic MRL but indicated that the intermediate MRL should be protective for chronic exposure (ATSDR 2013). Though HW17 relies on bottled water for their drinking water, ATSDR evaluated uranium exposure as a potential scenario. The first-draw uranium result for HW17 was 0.0065 mg/L, which could expose residents to uranium levels from 0.00022 to 0.00093 mg/kg/day for RME scenarios for adults to children younger than 1 year old, respectively. Though these doses exceed the MRL, the LOAEL is several orders of magnitude above the maximum dose. Exposure to uranium in drinking water does not appear to pose a risk for harmful health effects. However, the uncertainty associated with the potential for health effects would require additional evaluation to determine whether residents at HW17 can safely consume their water. Other homes whose wells contained uranium above the screening level had a maximum value of 0.0018 mg/L, which would only result in an RME dose above the MRL for children younger than 1 year old at 0.00026 mg/kg. ATSDR concludes that noncancer effects are unlikely for adults and children.

Uranium is a naturally occurring element that is found in the environment. Exposure to high amounts of uranium can result in harmful effects on the kidneys due to chemical effects (ATSDR

2013). The 2017 ATSDR EI sampling results discussed here are for the chemical form of uranium. Uranium is also a radioactive element. Appendix F summarizes EI sampling for radioactive contaminants, including uranium. No radioactive contaminants were present above drinking water standards.

Completed pathway hazard determination: Exposure to the levels of uranium detected in Dimock water supplies are not expected to result in adverse health effects.

Potential pathway hazard determination: If residents using the HW17 water supply resumed ingestion of this water, exposure to uranium through ingestion of drinking water may result in adverse health effects. Treatment to reduce uranium levels should be installed to eliminate the risk of adverse health effects.

D. Bromide, Iron, Lead, Lithium, and Sodium – Qualitative Assessment

Appendix E provides qualitative analysis of contaminants that do not have appropriate screening levels available. The conclusions of the qualitative evaluation are provided below:

- **Bromide**: Bromide was found in two first-draw samples and three raw water samples. Bromide is associated with extraction of oil and gas from shale formations. It was found at one residence at levels comparable to the Acceptable Daily Intake (ADI) recommended by WHO (WHO 2009). Adverse effects are not expected to result following ingestion of drinking water containing bromide at levels reported in Dimock in the 2017 EI.

- **Iron**: Iron was detected in nine water samples. Unless a resident is on an iron-restricted diet or has been diagnosed with an iron disorder such as hemochromatosis, the amount of iron detected in Dimock water supplies assessed in the 2017 ATSDR EI is not expected to cause adverse health effects from daily exposure.

- **Lead**: Lead was detected in 13 water samples, including one raw sample and one bulk sample detected above the EPA Action Level of 0.015 mg/L (0.024 mg/L at HW49-R and 0.072 mg/L at HW63-B). The first-draw sample at HW63, however, was treated prior to use. Lead was not detected in HW63 treated water. ATSDR recommends that residents in the Dimock area continue to treat their water to ensure removal of lead from their drinking water source. There is no safe blood lead level; lead in drinking water at any level may contribute to a child's blood lead level.

- **Lithium**: Three first-draw water samples had lithium concentrations that exceeded the CV, though only one location (HW18-F) uses their tap water as their primary source of drinking water. ATSDR recommends that water in the Dimock area be treated to remove lithium, especially in those homes with sensitive populations (such as residents who may be taking lithium therapeutically).

- **Sodium**: Sodium was found in every water sample taken in the Dimock EI. Residents who are not on a salt-restricted diet are not likely to experience adverse health effects based on the levels of sodium in the water supply.

ATSDR recommends that residents consider treatment for their drinking water in the Dimock area to remove all metals and ions detected in the water supply, since targeted removal of any one metal contaminant will result in the reduction of most of the metals and other contaminants in that water supply. HW18 should install and maintain water treatment to remove lithium from their water; all other homes did not have COC in drinking water at levels that would result in adverse health effects. In addition, ATSDR recommends that residents test their water regularly and run the water for at least 15-30 seconds before drinking the water to flush any accumulated metals from the water sitting in the pipes.

E. Petroleum Hydrocarbons

Petroleum contamination in water is often measured as total petroleum hydrocarbons (TPH), which is a mixture of many chemicals related to petroleum hydrocarbons. Instead of testing for total petroleum hydrocarbons, ATSDR used an analytical method to detect the presence of petroleum hydrocarbons tested for groups of chemicals (gasoline-range organic compounds, or GRO, and diesel-range organic compounds, or DRO) as well as hexane-extractible materials (HEM) Oil & Grease. These analyses were used in this EI to predict water source contamination possibly leading to health implications. TPH analyses, including DRO and GRO, can assist with identifying the sources of contamination in water supplies. Water containing TPH will generally have an unpleasant taste and smell.

Table 5: Petroleum Hydrocarbons Detected in Dimock Water Supplies

Sample ID	Water Source	Analyte	Result	Total Petroleum Hydrocarbons
HW01-F	Pond	Gasoline Range Organics (GRO)	**0.17** mg/L	0.64 mg/L
		Diesel Range Organics (DRO)	**0.47** mg/L	
HW06-F	Creek	Gasoline Range Organics (GRO)	0.059 J mg/L	0.059 J mg/L
HW18-F	**Well**	**HEM (Oil & Grease)**	**6.7 mg/L**	**6.7 mg/L**
HW18-R	Well	HEM (Oil & Grease)	12.4 mg/L	12.4 mg/L
HW22-F	Well	Diesel Range Organics (DRO)	0.11 J mg/L	0.11 mg/L
HW32-F	Well	HEM (Oil & Grease)	17.6 mg/L	17.6 mg/L
HW36N-	Well	HEM (Oil & Grease)	9.9 mg/L	9.9 mg/L
HW56-F	**Well**	**HEM (Oil & Grease)**	**8.4 mg/L**	**8.4 mg/L**
HW64-R	Spring	Diesel Range Organics	0.14 mg/L	0.14 mg/L

Notes: -F = first-draw sample collected from tap after treatment, if any installed; -R = raw water sample collected after purging plumbing lines; µg/L = micrograms per liter; mg/L = milligrams per liter; HEM = Hexane extractable materials; J = contaminant present in sample, concentration is an estimate. **Bold** indicates drinking water sample

Five well water sources, two surface water sources, and one spring water source had detectable levels of petroleum hydrocarbons. Two primary drinking water sources had petroleum hydrocarbon contamination (HEM Oil and Grease) in the first-draw tap samples collected from the kitchen tap. None of the other water supplies with petroleum contamination in first-draw samples are used for drinking water; these residences have alternative drinking water. One spring water sample had diesel-range organic compounds (DRO) in the raw sample, but it was not detected in the tap water sample. Hexane extractable materials (HEM Oil & Grease) were found in four wells at concentrations ranging from 6.7 to 17.6 mg/L. There is no health-based comparison value for HEM Oil & Grease.

Based on the methods used and the reported results, there is evidence that dissolved and degraded petroleum hydrocarbons were found in some water sources in the investigation area in the two first-draw tap samples where HEM Oil and Grease was detected. Although petroleum hydrocarbons are not commonly found in drinking water sources, surface water bodies are often contaminated with petroleum hydrocarbons due to surface runoff from roads and other sources. Without sufficient treatment, these sources of water are not recommended for household use or drinking water.

The presence of petroleum hydrocarbons in household, and particularly, drinking water supplies, is not common. As such, ATSDR used the presence of petroleum hydrocarbons in water as an indicator of a greater contamination issue in any sources in which they were detected. Though there are no health-based screening values for petroleum hydrocarbons, the constituents of both DRO and HEM categories include some chemicals that do have an association with adverse health effects (such as benzene, among others). **ATSDR recommends these contaminants be removed before water is used for household purposes and particularly if the water is used as a drinking water supply, as constituents of these categories of contaminants may contain chemicals associated with adverse health effects.**

F. Radon in Indoor Air and Water

Radon is the number one cause of lung cancer among non-smokers and is the second leading cause of lung cancer overall (EPA 2019b). Radon is believed to be responsible for about 21,000 lung cancer deaths every year (EPA 2019b). Based on community concerns, radon was tested both in water supplies and in indoor air (Table 6). ATSDR conducted a short-term (3-day) indoor air radon test in participants' homes, including basement air and the air in living spaces of the home. Elevated radon in indoor air is often due to infiltration of radon from under the home into the basement, similar to vapor intrusion. Basement air was tested to determine whether this is occurring. Radon was also tested in the living space of the home where participants use their well/spring water the most. Radon tests in living spaces provide an exposure concentration for comparison to the EPA action limit of 4 picocuries per liter (pCi/L).

To determine whether water use in the home is a source of radon in indoor air, radon was also tested in the water supplies used in participants' homes. The PADEP notes that for every 10,000 pCi/L of radon in the water, 1 pCi/L would be emitted into the air (PADEP 2014). The maximum radon detection in Dimock water supplies, at 3,558 pCi/L, would contribute approximately 0.36 pCi/L of radon gas to the air exposure pathway (similar to average outdoor background levels). For comparison, the EPA strongly recommends actions to reduce exposures inside the home when radon levels in the air exceed 4 pCi/L (EPA 2017b). The maximum concentration of radon detected in water would not be expected to add appreciable levels of radon to the indoor air.

In basement air tested during the 2017 EI, radon concentrations ranged from non-detect (less than 0.4 pCi/L) to 10.3 pCi/L. Eight of 20 homes with valid basement results had radon exceeding the screening level of 4 pCi/L (Table 6). In living spaces, nine homes had detectable radon concentrations below the EPA action level, ranging from 0.4 to 3.1 pCi/L, and one home had a radon concentration at the EPA action level of 4 pCi/L. Thirteen homes had no detectable radon in their first-floor air. For more information on radon exposure and health, visit EPA's website Health Risk of Radon at https://www.epa.gov/radon/health-risk-radon (EPA 2019b).

Inhalation exposure to radon in indoor air above 4 pCi/L may cause adverse health effects. **ATSDR recommends that residents consider longer-term radon testing and use radon mitigation measures as needed based on results.**

Table 6: Results of Indoor Air Radon Testing

Location	Basement	1st Floor
HW01	NA	NA
HW02	< 0.4	Invalid
HW03	2.6	0.4
HW06	**5.1**	1
HW12	Invalid	< 0.4
HW14	**6.2**	< 0.4
HW17	NS	< 0.4
HW18	2.5	1.8
HW21	NS	< 0.4
HW22	NS	< 0.4
HW25	< 0.4	< 0.4
HW28A	2.9	1.7
HW32	< 0.4	< 0.4
HW36	**7.7**	0.7
HW39	**5**	< 0.4
HW40	3.2	1.2
HW46	**5.8**	**4**
HW47	3.6	0.6
HW48	1.2	1.1
HW49	3.9	3.1
HW52	1	< 0.4
HW53	**5.4**	< 0.4
HW56	**10.3**	< 0.4
HW63	**4.1**	< 0.4
HW64	< 0.4	< 0.4

*Notes: All results in picocuries per liter (pCi/L); bold indicates result exceeds EPA screening level of 4 pCi/L, EPA screening level for air only (not water); * = The uncertainty in these measurements combines all the errors in the sample evaluation. This would include the error in the sample collection, sample measurement, and the error associated with identification. The uncertainty is also based on a distribution of all the samples. Typically, if the uncertainty is greater than the reported value, this indicates that the reported value is essentially zero. The closer the reported uncertainty is to the water concentration, the less significant the reported value.*

Radionuclides

ATSDR assesses radiological contaminants in drinking water by comparing results with appropriate drinking water standards such as the EPA maximum contaminant level (MCL). Though the MCL only applies as a regulatory value to public drinking water supplies, ATSDR also uses the MCL as a screening level for this class of contaminants. All radiological contaminants in water samples collected in the Dimock area were below EPA MCLs**.** Additional information regarding radionuclides assessment by ATSDR is provided in Appendix F.

VI. Conclusions

Based on the 2017 EI, ATSDR provides the following conclusions (see Appendix D, Table D.5 for summarized actual exposures and associated recommendations):

1. Drinking water quality is inconsistent in Dimock due to differences in source water selection, presence of contaminants in source water, and type and use of water treatment systems. These inconsistencies and the variability in groundwater quality has led to uncertainty in the community about which water source is the safest option for Dimock residents.
2. Except for select contaminants identified in Conclusion #3, breathing, drinking, or touching contaminants in water is not expected to result in adverse noncancer health effects or significant increases in excess lifetime cancer risks for most drinking water sources and exposure populations.
3. For a few chemicals and associated subpopulations, ATSDR identified the following public health concerns from exposures to specific contaminants and contaminant classes detected in water (see Appendix D, Table D.5 for completed exposures for specific residences/water sources):

Organic Compounds, including Trihalomethanes (THM)

Organic compounds were detected in the first-draw drinking water at one residence and in treated pond water (not typically used for drinking) at another residence.

- Breathing and touching organic contaminants in household water at HW01 is a concern for increased cancer risk due to multiple carcinogenic contaminants.
- None of the estimated organic compound contaminant exposures at this residence are expected to result in harmful noncancer health effects from ingestion exposure because residents do not currently drink the water.
- Exposure to 2-chlorovinyl ether through non-ingestion household use is unlikely to result in harmful skin effects. The lack of sufficient toxicological literature prevents ATSDR from making further conclusions on other health effects.

ATSDR also evaluated THMs through household use and the potential for inhalation and dermal exposure to THMs. Some households had THMs present in their water as disinfection biproduct of water treatment by treating the water with chlorine bleach.

- Water disinfection treatment resulted in the presence of trihalomethane (THMs) in drinking water at levels that can result in the potential for both noncancer and cancer effects, mostly due to the presence of chloroform.

Natural Gases

- Based on 2017 EI data, five homes have methane concentrations in water that enter the home at levels that increase the risk of fire/explosion hazards from gas buildup in enclosed spaces.

Metals and Major Ions

- Children are at greatest risk for adverse health effects from drinking water exposures to copper, lithium, and manganese at the levels detected in specific Dimock drinking water supplies. Sensitive subpopulations might experience adverse health effects from exposures to lithium, iron, and sodium at the levels detected in specific Dimock drinking water supplies.
- Except for the following specific conclusions, exposures to other metals and salts, including arsenic, barium, uranium, and fluoride, detected in Dimock water supplies by ATSDR in 2017 are not expected to result in adverse health effects.

Copper

- Children and especially small children, who will receive a higher copper dose from the water than adults due to body weight, might experience harmful noncancer health effects from exposure to copper at the maximum concentration detected in water.

Iron

- Concentrations of iron detected in Dimock water supplies assessed in the 2017 ATSDR EI, including the maximum detected iron concentration, is generally not expected to cause adverse health effects from daily exposure.

Lead

- Ingestion of lead in drinking water at any level may contribute to a child's blood lead level. There is no safe level of lead in the blood. Children and the developing fetus are especially at risk for adverse health effects from lead ingestion.

Lithium

- Lithium concentrations at one tap may harm people's health for some individuals, particularly sensitive populations, including those that may take therapeutic lithium.

Manganese

- One well contained manganese at a level were infants and children younger than 6 years of age might experience adverse neurological health effects from chronic consumption of water. Combined manganese exposures (i.e., food and drinking HW56 water) would also exceed the Long-Term Health Advisory (LTHA) level for children younger than 8 years of age. Drinking water that contains manganese at HW56 might harm children's health.

Sodium

- Residents who are not on a salt-restricted diet are not likely to experience adverse health effects, based on the sodium concentrations detected in Dimock water supplies.

Petroleum Hydrocarbons

- Petroleum hydrocarbons were detected in six Dimock water supplies in the EI and might indicate general contamination of the water. Some of the chemicals that might contribute to detections of petroleum hydrocarbons can cause harmful health effects,

Radon

- Radon concentrations found in Dimock water would not contribute appreciably to indoor air radon levels.
- Radon in indoor air in eight of 20 homes with valid basement results exceeded the screening level of 4 pCi/L. In living spaces, nine homes had detectable radon concentrations in air, ranging from 0.4 to 3.1 pCi/L, and one had a radon concentration at 4 pCi/L. Breathing radon in indoor air above 4 pCi/L can increase the risk for lung cancer.

Radiological Contaminants

- No radiological contaminants were detected above drinking waters standards.

VII. Limitations

There are several important limitations to the conclusions drawn on the environmental data collected during the 2017 ATSDR Exposure Investigation. Without sufficient data and to address some of these limitations, ATSDR used maximum exposure concentrations from all Dimock samples for both the screening and evaluation process. We assumed chronic exposures for each sample that was used to assess each residence because data was not available over a longer period. Additional limitations are provided below:

- The results of this investigation are only applicable to the 25 water sources tested. The results cannot be generalized to other populations because this investigation attempts to specifically target people in the Dimock area.

- Some analytes have detection limits higher than health-based comparison values. In this EI, arsenic was the only analyte with a detection limit above a comparison value. Arsenic was therefore reported as not detected above method detection limits and may have been present in the sample at levels of potential health concern.

- Sample data was collected from 25 residences during a discrete period. The data assessed may not represent exposures at other times; therefore, ATSDR cannot make public health conclusions about exposures outside the period the EI was conducted.

- Some of the Dimock residences that were included in the 2012 sampling that expressed interest in water testing during the ATSDR 2017 EI were not included in this EI. Untested Dimock residential water supplies are a data gap for assessing chemical exposures in this community.

VIII. Recommendations

ATSDR provided specific recommendations regarding contaminant exposures to acute hazards or the potential for an explosion hazard due to methane presence to homeowners in individual results letters in 2018. In addition to these recommendations that are summarized below, ATSDR recommends additional water testing for the Dimock residential wells and spring water sources used for drinking water that did not participate in the 2017 EI.

Organic Compounds (Other than Trihalomethanes)

Five organic compounds were detected in one water source: a surface pond selected by the homeowner as a water source to replace their well water for nondrinking water. Because exposure to contaminants in this water through inhalation during household use increases lifetime cancer risk and the potential for noncancer health effects, a whole-house treatment system is recommended for residents who still use this water source. For more information about treatment systems, contact the Penn State Extension office at 570-278-1158 and online at https://extension.psu.edu/water/drinking-and-residential-water) or contact a water treatment specialist to assist with this specific water supply's contaminants.

Trihalomethane (THM)

Treating surface water to be safe for drinking is important because of the presence of bacteria and other pathogens in source water. ATSDR recommends treating surface water sources for bacterial contamination before use. However, it is important to identify the correct amount of chlorine to effectively treat water for bacteria and pathogens while limiting the production of THMs. To achieve an appropriate level of chlorine in your water supply, ATSDR recommends contacting the Penn State Extension in Susquehanna County at 570-278-1158 or visiting the Penn State Extension web site at https://extension.psu.edu/water/drinking-and-residential-water. The Penn State Extension Office can provide recommendations for the continuous treatment of water with chlorine, shocking of systems to eliminate bacteria, and flushing lines to limit the levels of THM produced over time. That information is available at this website: https://extension.psu.edu/coliform-bacteria.

Public water supplies also use chlorine for treatment of bacterial contaminants, resulting in the production of THMs over time. To reduce the production of THMs in bulk storage, ATSDR recommends limiting the amount of time storing water in bulk "buffalo" storage tanks. ATSDR also recommends ventilating the home whenever possible to reduce buildup of chloroform in indoor air.

Natural Gas

To reduce the risk of safety hazards from natural gases in water supplies and health effects from exposure to contaminated household water supplies, ATSDR provides in Table 7 below general recommendations to the Dimock community.

Table 7: Recommendations for Elevated Natural Gas in Residential Water*

Concentration	Action Level	Recommendations
<10 mg/L	Awareness	• Conduct visual monitoring for effervescence (gas bubbles, milky water appearance) • Conduct regular laboratory testing to determine methane levels

Concentration	Action Level	Recommendations
10 to <28 mg/L	Precautionary	• Install combustible gas monitor in house • Ventilate wellhead and house • Test water regularly to determine methane levels • Conduct visual monitoring for effervescence
≥28 mg/L	Immediate	• Vent wellhead and house • Install treatment to remove gas before water enters house • Install combustible gas monitor in house • Test water regularly to determine methane levels • Conduct visual monitoring for effervescence

*7 mg/L established after the completion of the 2017 EI as concentration in which operator must notify PADEP and take necessary steps to protect health and safety if level is sustained at or above 7 mg/L in residential water supply.

Metals and Major Ions

For homes where metals and ions were found at harmful levels:

- To reduce exposure to metals and major ions in drinking water, ATSDR recommends that homeowners run the water for at least 15-30 seconds before use to flush the water lines.
- ATSDR recommends that an alternative source of water be obtained or that water be treated to remove all metals and major ions and that the treatment system be maintained according to manufacturer's recommendations.
- Individuals who have hemochromatosis, are on a low-salt diet, or are taking lithium therapeutically should discuss the levels of iron, sodium, and lithium, respectively, in their drinking water with their physician.

Manganese

ATSDR provides the following recommendations based on the concentration of manganese in drinking water:

Manganese Concentration	Recommendation
0.3 mg/L or less	Routine private water well monitoring, including analyses for manganese.
0.3 to 0.5 mg/L	Infants (birth to 1 year) use bottled water or use appropriate and properly maintained water treatment system with bi-annual water quality monitoring.
>0.5 mg/L	Infants and children use bottled water or use appropriate and properly maintained water treatment system with bi-annual water quality monitoring.
>1 mg/L	All age groups use bottled water or appropriate and properly maintained water treatment system with bi-annual water quality monitoring.

Petroleum Hydrocarbons

ATSDR recommends any concentration of these contaminants be removed by treatment before water is used for household purposes and particularly if the water is used as a drinking water supply. For information about treatment systems, contact the Penn State Extension office at 570-278-1158 and online at https://extension.psu.edu/water/drinking-and-residential-water.

Radon

ATSDR recommends that residents consider longer-term radon testing and use radon mitigation measures as needed based on results. ATSDR recommends residents consult the table below for EPA action recommendations appropriate for radon results from their home.

Radon Level	**Conclusion**	**Recommendation**	**Proportion of Dimock Homes**
<0.4 pCi/L	Radon not present; radon not a health risk if not present	Radon was not detected. No additional steps recommended	8/25
0.4 pCi/L	*Background level of radon in outdoor air*		
1.3 pCi/L	*Average indoor air radon level*		
0.4 to <2 pCi/L	Radon detected; lung cancer risk	Radon present above ambient outdoor air; consider taking steps to ventilate home and remove radon, especially if you smoke	2/25
2-4 pCi/L	Radon detected; increased risk of lung cancer	Take steps to fix your home and ventilate to remove radon gas in the air; stop smoking	6/25
>4 pCi/L	Radon elevated: higher risk of lung cancer	Take *immediate* steps to fix your home; stop smoking	8/25

pCi/L = picocuries per liter.
Source: https://www.epa.gov/radon/health-risk-radon

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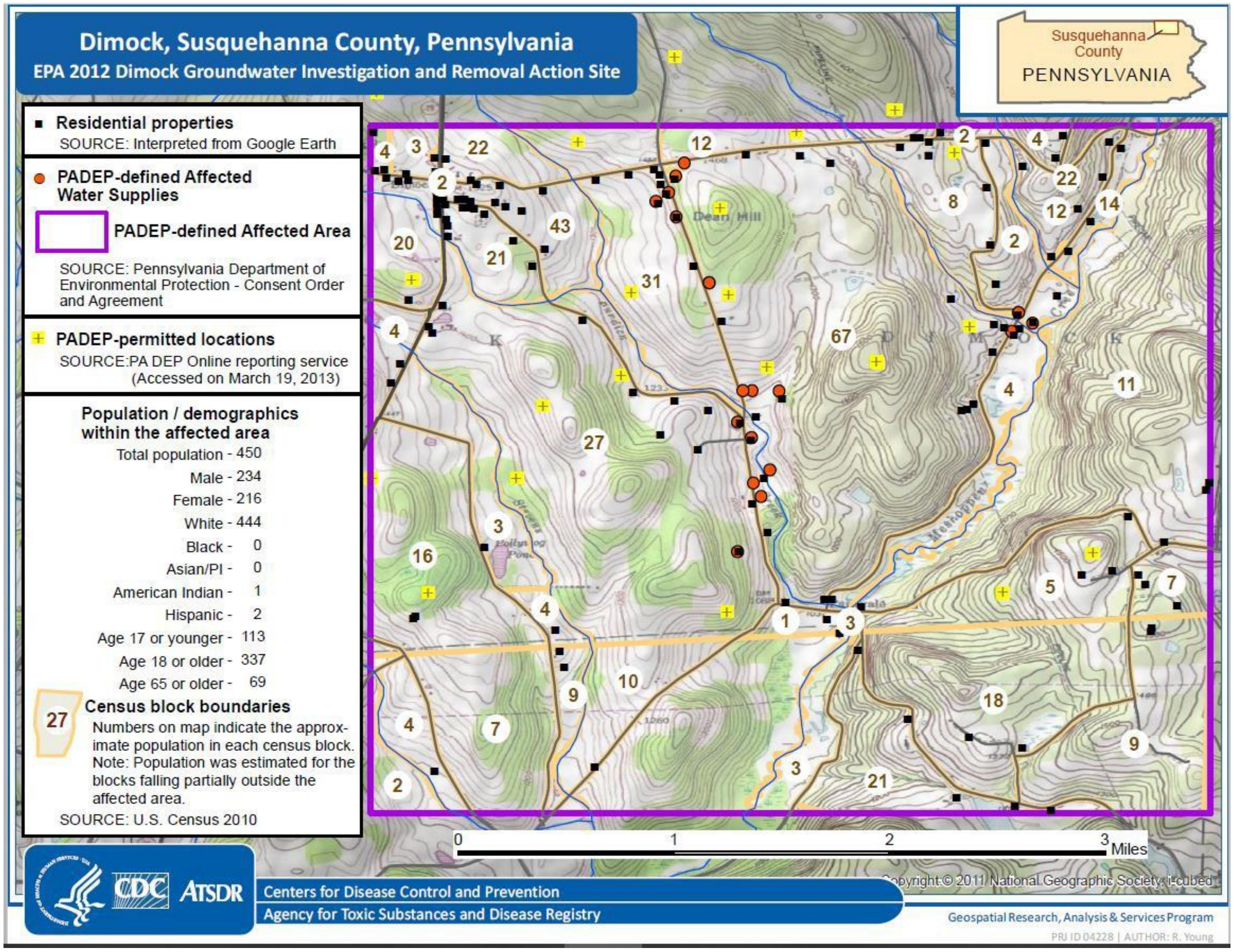
Appendix A: Exposure Investigation Map

Figure 1: Dimock Exposure Investigation, Dimock, PA – Investigation Area and Demographics



Appendix B: Water Sources and Treatment Systems

Table B-1 provides information on the use of private wells, springs, bottled water, bulk water and other water sources, and treatment system information for the households that participated in the EI. Of the 25 participating households, 21 homes use a groundwater well (18) or a natural spring (3) for household water uses; four households do not use their well for household water use. Nine of these 21 residences also use their onsite well (7 homes) or spring (2 homes) as a source for drinking water. A limited number of homes have treatment for chemical contaminants: five supplies are treated for household use only (all groundwater well sources) and five supplies (three wells and two bulk water sources) are treated for all uses (drinking water and household). None of the remaining residences (10 wells and three springs) have treatment systems other than sediment filtration. As their primary drinking water source, 13 residences use bottled water, and three residences use bulk water obtained from Montrose public water supply. Both of the sampled natural springs used as a source for drinking water have ultraviolet light (UV) to treat the surface water source for bacterial contamination but do not have treatment for chemical contaminants.

Table B-1: Water Source and Treatment System Use by Participants

Water Source	# Samples	Not Used for Household or Drinking Water	Only Used as Household/ Non-Drinking Water	Drinking Water Only		Has Treatment; Not Used for Drinking Water
				Used for Drinking Water	Has Treatment for Chemical Contaminants	
Well	22	4	11	7	3	5
Spring	3	0	1	2	0	0
Bulk (Montrose)	2	0	0	3*	2	0
Other (creek/pond)	2	0	2	0	0	0
Bottled	0	0	0	13	NA	NA
Totals	**29**	**4**	**14**	**25**	**5**	**5**

* One of the bulk water system (HW03) was not sampled because the source of the water was from a neighbor's home (see discussion below)

Samples Taken During the EI and Treatment Systems for Participants

Table B-2 provides information about water use, type of water samples collected during the EI, information provided by participants on their primary source of drinking water, and the known water treatment system components in their home. It is important to note that many residents have *multiple* water sources in use at their home including wells, springs, bulk or bottled water and alternative surface water supplies. Some residents use well water for household (e.g., cleaning, bathing) and drinking water purposes, while others use well water for household purposes only, and bottled or bulk water for consumption (see Table B-2).

Table B-2: Residential Well Characteristics, EI Sampling Summary, and Treatment Systems

Sample ID (# of samples)	Drinking Water Source	Household Water Source	Source of Water Samples Collected			Water Treatment System
			Tap 1st draw	Purged	Other	
HW14 (2)	Bottled	Well	Well	Well	No	CI: WH
HW17 (2)	Bottled	Well	Well	Well	No	WS, K-POU

Sample ID (# of	Drinking Water Source	Household Water Source	Source of Water Samples Collected			Water Treatment System
			Tap 1st draw	Purged	Other	
HW25 (2)	Bottled	Well	Well	Well	No	CF
HW36N (3)	Bottled	Well	Well	Well ǂ	No	CI: WH
HW39 (2)	Bottled	Well	Well	Well	No	CI: WH
HW40 (3)	Bottled	Well	Well	Well ǂ	No	WF
HW47 (2)	Well	Well	Well	Well	No	CI: K-POU, Chl, WS
HW56 (2)	Well	Well	Well	Well	No	K - POU
HW63 (2)	Bottled	Well	Well	Well	No	Sed, RO-POU
HW03 (2)	Bulk	Well	Well	Well	No§	None
HW18 (2)	Well	Well	Well	Well	No	Sed
HW21 (3)	Bottled	Well	Well	Well ǂ	No	None
HW22 (2)	Bottled	Well	Well	Well	No	None
HW32 (3)	Supplied bulk	Well	Well	Well ǂ	No	None
HW46 (1)	Well	Well	Well	No	No	Sed
HW48 (2)	Well	Well	Well	Well	No	None
HW49 (2)	Well	Well	Well	Well	No	Sed
HW53 (2)	Well	Well	Well	Well	No	Sed
HW12* (2)	Bottled	Spring	Spring	Well	No	None
HW28a (2)	Spring	Spring	Spring	Spring	No	UV, S, WS
HW64 (2)	Spring	Spring	Spring	Spring	No	UV
HW01* (2)	Bottled	Pond	No	No	Holding Tank ǂ	SH
HW06* (2)	Bottled	Creek	Creek	Well	No	SH
HW02* (3)	Bulk	Bulk	Bulk	Well	Raw Bulk	K-POU
HW52† (4)	Bottled	Bulk	Bulk	Well (raw)	Raw Bulk ǂ	RO-POU
--	**Total Sample Count** (Duplicate Sample Count)		**24**	**23** (4)	**3** (2)	-

* groundwater well not used; §raw bulk water source exists but not tested; †well not used inside home; ǂ duplicate sample collected.

Abbreviations: ID = Identifier; Treatment Systems information: CF = Carbon filter cartridge, Chl = Chlorinator, CI = Cabot-installed system, K = Kitchen, POU = Point of use system (components unknown), RO = Reverse osmosis, Sed = Sediment filter, SH = Sodium hypochlorite (bleach) by hand, WF = Water Filter, components unknown, WH = Whole house filtration, WS = Water softener, UV = Ultraviolet light

Four EI participants have disconnected their wells from their household plumbing and their wells are not in use (one of these resident's disconnected wells could not be sampled during this EI due to wellhead access issues). One additional participant who disconnected their well from the home plumbing uses the well water only for outdoor purposes.

Seven of the wells included for sampling in the EI are used as the household's primary drinking water source; three of these seven wells are treated at the kitchen tap for chemical contaminants (not including supplies treated with sediment filters, water softeners, and UV light). Two natural springs, both without chemical treatment systems, are used as primary drinking water sources (both have UV light to treat for bacteria). Three homes use bulk water supplies as their primary drinking water sources; two of these homes also have point-of-use chemical treatment (i.e., treatment only on the primary drinking water tap) for their bulk water supplies. Finally, families in 13 of the 25 homes assessed in the EI use bottled water as their primary source for drinking water in their homes.

Due to concerns about well water quality, two residents have chosen to use bulk water from the Montrose public water supply as their main source for household water, including for drinking and cooking. Both of these residents also have point-of-use filtration systems that treat their bulk water supplies at the kitchen tap. Additionally, one participant (HW03) collects large jugs of bulk water from a neighbor's home (neighbor's source is also the Montrose public water supply) and uses this water as their primary source for drinking and cooking; this bulk water was not tested as part of the 2017 EI. Three other residents have chosen to use surface water as their source for household water (spring, creek and pond water); each of these residents collect the water into bulk containers outside their home (one cistern, 2 “buffalo” tanks) and all three use bottled water as their primary source for drinking water. Two of these residents add household bleach (i.e., sodium hypochlorite) to their holding tank at varying times and concentrations to address bacteria in the source water. HW01 was the only residence that did not have radon analysis conducted.

Appendix C: Results of COC Screening

Table C.1 includes contaminants that had comparison values (CVs) used to screen the 2017 EI data set. Table C.2 provides the maximum concentration and the frequency of detection of COCs in each unique water source sampled in the 2017 EI data set, and information regarding screening levels and exceedances of the screening level. All COCs with at least one CV exceedance were further evaluated.

Table C.1 Contaminants* Screened in 2017 EI

Contaminant	CV Value (µg/L)	CV Source	Frequency of Detection	Exceedances /Detections	Maximum Concentration
1,2-Dibromoethane (EDB)	0.012	CREG	1/29 (3%)	1/1 (100%)	0.68
2-Butanone (MEK)	4200	RMEGc	No detects above CV		
2-Chloroethyl vinyl ether	NA	NA	1/29 (3%)	NA	24
Acetone	6300	RMEGc	0/29	NA	NA
Acetophenone	700	RMEGc	0/29	NA	NA
Aluminum	7000	cEMEGc; iEMEGc	1/29	0/29	6,050
Arsenic	0.016	CREG	7/29 (24%)	7/7 (100%)	91
Barium	1400	cEMEGc, iEMEGc, RMEGc	29/29 (100%)	5/29 (17%)	5,300
Benzaldehyde	700	RMEGc	0/29	NA	NA
Beryllium	14	cEMEGc RMEGc	4/29	0/4	2
Bis(2-ethylhexyl) phthalate	0.7	iEMEGc	1/29 (3%)	1/1 (100%)	3.5
Boron	1400	iEMEGc; RMEG; aEMEGc	13/29	0/13	534
Bromide	NA	NA	3/29 (10%)	NA	1,500
Bromodichloromethane	0.39	CREG	5/29 (17%)	5/5 (100%)	13
Bromoform	3.1	CREG	0/29	NA	NA
Bromomethane	9.8	RMEGc	0/29	NA	NA
Butane	NA	NA	3/29 (10%)	NA	1.2
Butyl benzyl phthalate	1400	RMEGc	6/29	0/6	0.49 J
Calcium	NA	NA	21/29	0/21	42,400
Carbon disulfide	700	RMEGc	0/29	NA	NA
Carbon tetrachloride	0.35	CREG	1/29 (3%)	1/1 (100%)	0.57
Chloride	NA	NA	24/29	0/24	235,000
Chlorobenzene	140	RMEGc	0/29	NA	NA
Chlorodibromomethane	0.29	CREG	4/29 (14%)	4/4 (100%)	1
Chloroethane	21000	RSL-child	0/29	NA	NA

Contaminant	CV Value (µg/L)	CV Source	Frequency of Detection	Exceedances /Detections	Maximum Concentration
Chloroform	70	cEMEGc; RMEGc	7/29 (25%)	2/7 (29%)	670
Chloromethane	1900	RSL - child	0/29	NA	NA
Copper	70	iEMEGc	21/29 (72%)	3/21 (14%)	360
Diesel Range Organics [C10-C28]	NA	NA	3/29 (10%)	NA	470
Diethyl phthalate	5600	RMEGc	0/29	NA	NA
Di-n-butyl phthalate	700	RMEGc	3/29	NA	0.53
Di-n-octyl phthalate	2800	iEMEGc	0/29	NA	NA
Ethane	NA	NA	9/29 (31%)	NA	430
Fluoride	800	RSL-child	29/29 (100%)	4/29 (14%)	2,400
Gasoline Range Organics (GRO)-C6-C10	NA	NA	2/29 (7%)	NA	170
HEM (Oil & Grease)	NA	NA	5/29 (17%)	NA	17,600
Iron	300	SMCL	23/29 (79%)	9/23 (39%)	6,400
Lead	15	EPA Action Level	12/29 (41%)	2/12 (17%)	72
Lithium	40	RSL-child	26/29 (90%)	7/26 (27%)	300
Magnesium	NA	NA	21/29	0/21	125,600
Manganese	300	RSL - child - no diet	29/29 (100%)	10/29 (17%)	1,200
Methane	15000	DOI	17/29 (59%)	5/17 (29%)	15,000
Methanol	14000	RMEGc	0/29	NA	NA
Methylene Chloride	6.1	CREG	0/29	NA	NA
Naphthalene	140	RMEGc	2/29	0/2	0.37
n-Butylbenzene	1000	RSL - child	0/29	NA	NA
Nickel	140	RMEGc	8/29	0/8	2.1
Phenol	2100	RMEGc	1/29	0/1	100
Potassium	NA	NA	20/29	0/20	6,973
Propane	NA	NA	4/29 (14%)	NA	8.2
Silver	35	RMEGc	1/29	0/1	0.058 J B
Sodium	NA	NA	29/29 (100%)	29/29 (41%)	99,000
Strontium	4200	RMEGc	17/29	0/17	2,170
Styrene	1400	RMEGc	0/29	NA	NA
Sulfate	NA	NA	0/29	NA	NA
Tin	2100	iEMEGc	0/29	NA	NA
Titanium	NA	NA	2/29 (7%)	NA	5.4
Toluene	560	RMEGc	0/29	NA	NA
trans-1,2-Dichloroethene	140	RMEGc	0/29	NA	NA
Trichlorofluoromethane	2100	RMEGc	0/29	NA	NA

Contaminant	CV Value (µg/L)	CV Source	Frequency of Detection	Exceedances /Detections	Maximum Concentration
Uranium	1.4	iEMEGc - uranium sol salts	14/29 (48%)	7/14 (50%)	6.5
Vinyl chloride	0.017	CREG	1/29 (3%)	1/1 (100%)	0.32
Zinc	2100	cEMEGc; iEMEGc; RMEGc	12/29	0/12	930

* Contaminants with health-based screening values
CREG = Cancer Risk Evaluation Guide; DOI = Department of the Interior; cEMEGc = Chronic Environmental Media Evaluation Guide – child; iEMEGc = Intermediate Environmental Media Evaluation Guide – child; RMEGc = Reference Dose Media Evaluation Guide – child
RSL = Regional Screening Level (EPA); SMCL = Secondary Maximum Contaminant Level

Some residences have bulk or other alternative water sources for household and/or drinking use. Bulk water is water delivered by homeowners or by a Cabot contractor to Dimock residents, who use these supplies as sources of household and drinking water in place of their groundwater well supply. Alternate water supplies are water sources chosen by homeowners in place of groundwater wells for use only as household water supplies and these alternate water supplies are not used for drinking or cooking. Bulk and alternate water supply samples were collected and analyzed during this EI to determine whether these water supplies, chosen as alternatives to groundwater and spring water supplies, contain any contaminants at levels of health concern.

Bulk Water Sampling Results

Bulk water supplies were tested at residences where bulk water is used as a source for drinking water (Table C.2). Bulk water sampling was conducted because residents were concerned about the quality of provided bulk water. Because the water is used as an alternate to the private well and spring water that Dimock residents previously relied upon for their source of household and drinking waters, ATSDR assessed exposures to these alternate water supplies following delivery and storage in residential holding tanks. Two Dimock residences that participated in the EI use bulk water as a source for both drinking water and household use (both residents also use bottled water). The bulk water was treated prior to drinking water use; therefore, the bulk water sources were evaluated for dermal and inhalation exposure associated with household water use but was not evaluated for oral exposure.

- HW02 – This resident collects water from the Montrose public water supply tap and transports the water by tank truck to fill the bulk storage tank located at their residence. Resident has point-of-use (POU) treatment system at kitchen tap for treating bulk water immediately before drinking/cooking use.
- HW52 – Resident receives bulk water for household use, including drinking/cooking, by tank delivery under contract by Cabot. Resident has bulk water tank in garage and POU reverse osmosis treatment system in kitchen for drinking/cooking use.

Trihalomethanes, or THM, including bromodichloromethane, chlorodibromomethane, and chloroform, were present in untreated samples, but were removed by treatment prior to drinking water use at these two residences. Fluoride and sodium were present above screening levels in the first draw (post-treatment) and raw water samples at HW02. Lead, copper, fluoride and sodium were detected above screening levels in the raw bulk water at HW52 (collected from untreated kitchen tap) but were below screening levels in the first draw sample collected from the residence's tap (following the point-of-use reverse osmosis water treatment).

Table C.2: Bulk Water Contaminants that Exceed Screening Level

Sample Identifier	Analyte Class	Analyte	Raw Bulk Water	Treated Water	Screening Level	Screening Level Source
HW02	THM	Bromodichloromethane	**3.2**	ND	0.39	CREG
		Chlorodibromomethane	**1**	ND	0.29	CREG
		Chloroform	16	0.58	70	cEMEGc
	Major Ions	Fluoride	**790**	**780**	350	cEMEG
		Sodium	**53,000**	**53,000**	20,000	EPA DWL
HW52	THM	Bromodichloromethane	**6.5***	ND	0.39	CREG
		Chlorodibromomethane	**1***	ND	0.29	CREG
		Chloroform	42	ND	70	cEMEGc
	Metals	Copper	**180**	ND	70	iEMEGc
		Lead	**72**	ND	15#	EPA Action Level
	Major Ions	Fluoride	**800**	97	350	cEMEG
		Sodium	**57,000**	13,000	20,000	EPA DWL

Notes: results in micrograms per liter (µg/L); **bold** indicates concentration exceeds screening level; * = results presented are from higher duplicate results; DWL = EPA drinking water advisory level; ND = Not detected above method detection limit; cEMEG = Chronic duration Environmental Media Evaluation Guide (ATSDR value); iEMEG = Intermediate duration Environmental Media Evaluation Guide (ATSDR value); CREG = Cancer Risk Evaluation Guide (ATSDR value); THM = trihalomethanes are organic byproducts of disinfection process, #- there is no safe level of lead in water

Alternate Water Supply Sampling Results

Alternate water sources were sampled from storage tanks previously filled by residents from a pond or creek on their property. These water supplies were used exclusively for household purposes other than consumption (i.e., drinking and cooking). However, exposures to contaminants in the water can still occur while using the water for other household purposes, particularly during and after showering (i.e., ingestion of water during showering or bathing, inhalation of vapors produced during water use in the home, and dermal exposures from direct contact when bathing, washing, etc.) Therefore, when a participant noted they used alternative water, ATSDR offered to sample that water supply. Water sampling results were then evaluated by ATSDR using the ATSDR SHOWER model to determine inhalation and dermal exposure levels in these homes.

Both residents (HW01 and HW06) treat their alternative water supply before household use by adding sodium hypochlorite (household bleach) to the holding tanks to treat the water for biological contaminants. EI results indicate that both treated household water supplies do not have coliform bacteria present (Table C.3). However, degradation products from chlorine treatment (i.e., THMs) were present in these household water supplies at levels well above the EPA maximum contaminant level (MCL) for THMs in public water supplies. Although these water sources are not used as a source of drinking water, they are initially screening using drinking water comparison values. Further, ATSDR assessed ingestion as a potential drinking water pathway and to present a more detailed picture of Dimock's water quality and the risks associated with its use as drinking water. Some of the contaminants, due to their chemical properties, were also evaluated for inhalation and dermal exposures (which occur during household use) using the ATSDR SHOWER model.

Potential Ingestion Exposure Evaluation for HW01 Treated Pond Water

Bis(2-ethylhexyl) phthalate (DEHP)

Bis(2-ethylhexyl)phthalate (di(2-ethylhexyl) phthalate or DEHP) was detected at 3.5 micrograms DEHP per liter water (µg/L) in the HW01's , chlorine-treated pond water stored in holding tank. Though the residents affirmed to ATSDR during the EI that they do not drink this water, the concentration of DEHP detected exceeds ATSDR's health-based comparison value, or CV, of 0.7 µg/L (ATSDR intermediate Environmental Media Evaluation Guide, or iEMEG) and was evaluated for oral exposure in PHAST. The value of 3.5 µg/L is also above the Cancer Risk Evaluation Guide or CREG of 1.7 µg/L.

Bis(2-ethylhexyl)phthalate has an oral RfD of 20 µg/kg/day and an intermediate MRL of 0.1 µg/kg/day, which is well below the chronic RfD (there is no chronic MRL available). PHAST uses the intermediate EMEG (derived using the intermediate MRL) to screen the data and the oral RfD to derive the HQ. The ELCR was 4E-05 for dermal exposure, which is 4 additional cancers among 100,000 persons exposed. This value exceeds one excess cancer in a million people (1E-06); this cancer risk is not a public health concern. The chronic HQ for any pathway of exposure did not exceed one, although the intermediate oral HQ was 5, which exceeds an HQ of one.

The RfD of 20 µg/kg/day is based on a study from 1953 that reported increased relative liver weight in a subchronic study in guinea pigs (Carpenter et al., 1953). The intermediate MRL was based on developmental effects in an animal study from 2015 (Zhang et al. 2015). The toxicological profile and associated MRL values are currently under review by ATSDR, but ATSDR toxicologists have directed that PHAST use the oral RfD to derive a chronic for bis(2-ethylhexyl)phthalate. In addition, the detected value is a laboratory estimated value, which indicates uncertainty in the detected value.

Potential pathway hazard determination: ATSDR concludes that oral exposures to bis(2-ethylhexyl) phthalate in household water at HW01 is not a health concern for noncancer or cancer health effects.

Vinyl chloride

Vinyl chloride was detected in HW01-F (chlorine-treated pond water from holding tank) at 0.32 µg/L. This level exceeds ATSDR's health-based CV of 0.017 µg/L (CREG). As such, ATSDR conducted further toxicological evaluation and determined that the HQs for all age groups was below one. Ingestion of vinyl chloride in drinking water is unlikely to cause noncancer adverse health effects.

The ELCR was 9E-06 for oral exposure, which is 9 additional cancers among 1,000,000 persons exposed. This value exceeds one excess cancer in a million people (1E-06); this risk is not a public health concern. The chronic HQ for any pathway of exposure did not exceed one. In addition, the detected value is a laboratory estimated value, which indicates uncertainty in the detected value.

Potential pathway hazard determination: ATSDR concludes that oral exposures to vinyl chloride in first-draw water at HW01 is not a health concern for noncancer or cancer health effects.

Both alternate sources of water are collected from surface water bodies; therefore, common surface water contaminants are present in these supplies, including petroleum hydrocarbon chemicals (gasoline range and diesel range organics), metals (lead, iron, titanium) and salts (sodium).

Table C.3: Contaminants that Exceed or Have No Screening Level in Alternate Water Supplies

Sample Location	Creek water (HW06-F)	Pond Water (HW01-F)	Units	Screening Value	Screening Value Source
Analyte	**Result**	**Result**			
Trihalomethanes (organic byproducts of disinfection process) *					
Total Trihalomethanes	**202.73**	**684.7**	µg/L	**80**	**MCL**
Bromodichloromethane	**12**	**13**	µg/L	0.39	CREG
Chloroform	**190**	**670**	µg/L	70	cEMEGc
Chlorodibromomethane	**0.73 J**	**0.64 J**	µg/L	0.29	CREG
Bromoform	ND	1.1	µg/L	3.1	CREG
Major Elements and Salts					
Iron	120	**780**	µg/L	300	SMCL
Lead	1.1 J	<1.0	µg/L	15	EPA Action Level
Titanium	ND	3.8 J	µg/L	NA	NA
Sodium	5.2	**40**	mg/L	20	EPA DWL
Organic Compounds *					
1,2-Dibromoethane (EDB)	ND	**0.68 J**	µg/L	0.012	CREG
Bis(2-ethylhexyl) phthalate	ND	**3.5 J**	µg/L	1.7	CREG
Carbon tetrachloride	ND	**0.57 J**	µg/L	0.35	CREG
Vinyl chloride	ND	**0.32 J**	µg/L	0.017	CREG
2-Chloroethyl vinyl ether	ND	24	µg/L	NA	NA
Petroleum Hydrocarbons	59 J	640	µg/L	NA	NA
Diesel Range Organics (DRO)	ND	470	µg/L	NA	NA
Gasoline Range Organics (GRO)	59 J	170	µg/L	NA	NA

Notes: **Bold** indicates exceeds screening value; *= inhalation and dermal exposures assessed for these chemicals with ATSDR SHOWER model; µg/L = micrograms per liter; CREG = ATSDR cancer risk evaluation guideline; cEMEGc = chronic environmental media evaluation guideline for children; DWL = Environmental Protection Agency Drinking Water Equivalency Level; MCL = Maximum Contaminant Level; SMCL = Secondary Maximum Contaminant Level; NA= No screening level is available; J = chemical present, value is an estimate; ND = not detected above method detection limit

Additional organic contaminants were detected in pond water at trace amounts that exceed ATSDR lifetime cancer risk screening levels or for which no screening level has been identified. Although these water sources are not used for consumption, assessment of exposures during other household uses (e.g., inhalation during showering) is included in the assessment.

Appendix D: Quantitative Exposure Assessment Information

The Public Health Assessment Site Tool (PHAST) and the ATSDR Shower and Household Water-use Exposure (SHOWER) model were used to evaluate exposure to contaminants in the water supply via ingestion exposure as well as inhalation and dermal contact as the result of household use of water (ATSDR 2020). PHAST is an internal ATSDR tool that houses many sources of toxicological information. PHAST is used to screen contaminants for further assessment, calculate exposure doses, compare site doses and concentrations to relevant toxicological values (such as MRLs), and calculate cancer risks and HQs. Further information on the SHOWER model can be found in the Resources section of PHAST.

The SHOWER model's default assumption is for a 4-person household. However, ATSDR collected data on household size for each residence. As such, the SHOWER model was run using household-specific information for each home that had THM or organic contaminants exceeding the PHAST screening level. ATSDR evaluated the SHOWER model under a worst-case scenario with the assumption that all showers were being taken consecutively in the morning. Results were reported for the most highly exposed person, who is assumed to remain at home all day and not use a bathroom fan.

Table D.1 provides an analysis of oral exposure to the raw and bulk water, in addition to the inhalation and dermal results, in the event that the treatment system is removed from the home or if the treatment systems are not maintained as recommended. For homes that use well or spring water also treat their water, raw water is considered an "incomplete" pathway due to the water treatment system. Table D.2 provides the results of the SHOWER model for volatile COCs for all completed exposure pathways. Table D.3 provides a summary of potential and completed exposures for ingestion, inhalation and dermal pathways and the associated HQs and ECLR for all water sources and D.4 provides a listing of trihalomethane (THM) constituents to evaluate potential issues associated with treatment of water sources with bleach.

Additional Quantitative Discussion: Manganese

Manganese is a naturally occurring element found in many types of rock and soil; however, anthropogenic (man-made) sources cause elevated levels in groundwater. Manganese is also an essential dietary nutrient. The Food and Nutrition Board of the National Research Council has established Estimated Safe and Adequate Daily Dietary Intake Levels for this nutrient that range from 0.3 mg/day for infants to 5 mg/day for adults (IOM 2000). IOM identifies a tolerable upper intake level (UL), a daily amount that is considered to be safe for almost everyone to take, of 2-3 mg/day for 1-8 year old children; 6 mg/day for 9-13 year old children; 9 mg/day for children between 14 and 18 years of age; and, 11 mg/day for adults (IOM 2010). (Note, these ULs include manganese from all sources, including food, water, and supplements). For most people, food is the primary source of manganese exposure with the average dietary intake ranging from approximately 2 to 8.8 mg/day (WHO 2001). Exposure to manganese from drinking water is in addition to manganese in a daily diet.

In first-draw water, manganese was found in two wells above the CV of 0.43 mg/L (EPA RSL): HW12-F at a concentration of 0.95 mg/L and HW56-F at a concentration of 0.62 mg/L. Residents with the maximum manganese level in tap water (HW12 at 0.950 mg/L) do not use their tap water for consumption; instead, they use bottled water as their primary source for consumption. The maximum manganese concentration detected in water used as the primary drinking water source was 0.620 mg/L in HW56-F. This was the only drinking water sample collected from a primary drinking water source that had manganese above the health-based comparison value of 0.43 mg/L (EPA RSL). All other drinking water samples had manganese results below health-based screening levels.

Manganese was also found in raw water above the CV at HW47-R at 1.2 mg/L and HW63-R at 1.1 mg/L. The CV is based on a Regional Screening Level (RSL) of 0.43 mg/L. Treatment of the water in HW47-R should remove manganese to much lower levels (0.026 mg/L in HW47-F) before it is used from the kitchen tap.

ATSDR does not provide a chronic MRL or a chronic CV for manganese but notes that a dietary RfD of 0.14 mg/kg/day is available from EPA. However, this value should not be used to evaluate drinking water exposure from manganese. ATSDR completed a toxicological evaluation by assessing the toxicological profile for manganese, specifically studies associated with neurological effects in humans, and comparing these studies to site-specific doses in drinking water (ATSDR 2012b). An evaluation of these studies is provided below in the discussion and Table D.1.

The EPA has identified an RfD for manganese of 0.05 mg/kg/day. For this evaluation, ATSDR used the scientific literature to select the lowest observed adverse effect level (LOAEL) of 0.07 mg/kg/day to compare with the estimated manganese exposure dose from HW56 drinking water (Table D.1). In Table D.1, the toxicological studies used to select the mid-range LOAEL of 0.07 mg/kg/day are summarized. ATSDR used this information to generate a summary table of protective public health recommendations for private well water users to consider (see Table D.2). ATSDR calculated exposure doses for several age groups (infants, children, adults) to develop these recommendations using age-specific maximum intake assumptions.

Table D.1: Summary of Manganese Drinking Water Studies with Neurological Endpoints Used in the Selection of a Lowest Observed Adverse Effect Level (LOAEL) for Evaluation Purposes (in mg/kg/day)

LOAEL	Reference	Population	Exposure Duration (years)	Endpoint
0.06	Kondakis *et al.* 1989	Adult	50	Neurological
0.06	Woolf *et al.* 2002	Children	5	Neurological
0.07	Wasserman *et al.* 2006	Children	10	Neurological
0.08	Wasserman *et al.* 2011	Children	8+	Neurological

Chronic exposures to manganese can be harmful to human health. Manganese exposure at an average concentration of 0.793 mg/L has been shown to be associated with reduced full-scale performance and verbal raw scores in children in Bangladesh who consumed drinking water with high levels of manganese for 10 years (Wasserman *et al*., 2006). In a more recent study by Wasserman *et al*. (2011), manganese exposures greater than 0.5 mg/L (mean of 0.725 mg/L) resulted in lower perceptual reasoning and working memory scores after 8 years or more of exposure.

The estimated maximum chronic manganese exposure doses for children under 2 years of age consuming HW56 water daily (0.620 mg/L) ranges from 0.049 up to 0.088 mg/kg/day, at or exceeding the EPA RfD of 0.05 mg/kg/day. Children under one year of age may be exposed to manganese levels exceeding ATSDR's selected health guideline of 0.07 mg/kg/day. Children between 6 and 21 years of age have estimated maximum manganese exposure doses between 0.021 and 0.027 mg/kg/day. For adults consuming HW56 water daily, the maximum manganese exposure doses ranged from 0.024 mg/kg/day up to 0.030 mg/kg/day. Maximum estimated manganese exposure doses from HW56 water for children over 6 years of age and adults, fall below the LOAEL of 0.07 mg/kg/day and the EPA RfD of 0.05 mg/kg/day. Children under the age of two that consume HW56 water at the RME ingestion level may experience adverse neurological health effects.

Additional exposures to manganese from foods would increase the daily dose and the risk of health effects. When adding typical manganese exposures from food (2.6-3.8 mg/day) with manganese exposure from HW56 drinking water (1.9 mg/day), the daily exposure for all populations is estimated to be 4.5 to 5.7 mg/day. This combined manganese exposure level from food and HW56 water consumption exceeds the UL for 1-8 year-old children but is below the UL for children older than 9 years of age and adults.

Infants and children under six years of age may experience adverse neurological health effects from chronic consumption of water containing 0.620 mg/L of manganese (level measured in HW56 well water). Combined manganese exposures (i.e., food and drinking HW56 water) would also exceed the UL for children under 8 years of age. Table D.2 summarizes ATSDR's general public health recommendations for manganese in drinking water.

Table D.2: General Public Health Recommendations for Manganese in Drinking Water

Manganese Concentration	Recommendation
300 µg/L or less	Routine private water well monitoring, including analyses for manganese.
300 to 500 µg/L	Infants (birth to 1 year) use bottled water or use appropriate and properly maintained water treatment system with bi-annual water quality monitoring.
>500 µg/L	Infants and children use bottled water or use appropriate and properly maintained water treatment system with bi-annual water quality monitoring.
>1,000 µg/L	All age groups use bottled water or appropriate and properly maintained water treatment system with bi-annual water quality monitoring.

Although residents do not use HW12 tap water for regular consumption, the maximum tap water manganese level in the 2017 EI data set was detected in this supply (0.950 mg/L). If residents decide to use this water for consumption, exposures for children may result in harmful health effects from ingestion of manganese in the water. If children consumed HW12 tap water daily, the estimated maximum chronic manganese exposure doses would range from 0.14 mg/kg/day for children under 1 year of age down to 0.074 mg/kg/day for children between 1 and 2 years of age. Estimated chronic exposure doses for children under 2 years of age are above the level where health effects were observed in the literature (see Table E.1, LOAEL of 0.07 mg/kg/day). Children older than 2 and under 21 years of age would have estimated exposure doses between 0.053 and 0.032 mg/kg/day, respectively. For adults consuming HW12 water daily, the maximum manganese exposure doses would range from 0.034 mg/kg/day up to 0.047 mg/kg/day.

If tap water was consumed at HW12, the maximum estimated manganese exposure doses for children under 2 years of age would exceed the LOAEL and may result in adverse neurological health effects from chronic consumption of this water supply. Chronic exposures for children over 6 years of age and adults would not exceed the LOAEL of 0.07 mg/kg/day; however, maximum exposure scenarios for children between 2 and 6 years of age would exceed the EPA RfD of 0.05 mg/kg/day. This evaluation shows that harmful health effects are unlikely to occur for children and adults over 6 years of age.

Table D.3: Exposure Dose, Hazard Quotient, Cancer Risk: Ingestion of Drinking Water

Location	Sample Type	Exposure Pathway Complete?	Contaminant	EPC[1] (mg/L)	Oral Exposure Dose[2] (mg/kg/day)	RME HQ [2]			RME ELCR[3]
						Chronic	Intermediate	Acute	
HW01	First-draw	Incomplete	Bis(2-ethylhexyl) phthalate[4]	0.0035	5E-04	0.025	**5**	0.17	9E-07
HW01	Raw	Incomplete	Bromodichloromethane[5]	0.013	1.9E-03	0.23	NC	0.026	**2E-05**
HW01	Raw	Incomplete	Carbon Tetrachloride[6]	0.00057	8.1E-05	0.02	0.12	0.0041	8E-07
HW01	Raw	Incomplete	Chloroform[7]	0.67	9.6E-02	**9.6**	0.96	0.32	**6E-04**
HW01	Raw	Incomplete	Vinyl Chloride[8]	0.00032	4.6E-05	0.015	NC	NC	**9E-06**
HW01D	Raw	Incomplete	1,2-Dibromoethane (EDB)[9]	0.00068	9.7E-05	0.011	NC	NC	**3E-05**
HW01D	Raw	Incomplete	Bromodichloromethane[5]	0.013	1.9E-03	0.23	NC	0.026	**2E-05**
HW01D	Raw	Incomplete	Carbon Tetrachloride[6]	0.00054	7.7E-05	0.019	0.011	0.0039	7E-7
HW01D	Raw	Incomplete	Chlorodibromomethane[10]	0.00064	9.1E-05	0.001	NC	0.00091	**1E-06**
HW01D	Raw	Incomplete	Chloroform[7]	0.59	8.4E-02	**8.4**	0.84	0.28	**5E-04**
HW01D	Raw	Incomplete	Vinyl Chloride[8]	0.00026	3.7E-05	0.012	NC	NC	**7E-06**
								HW01 Total Excess Cancer Risk	Incomplete Exposure
HW02	First-draw	Incomplete	Fluoride[15]	0.78	0.11	**2.2**	NA	NA	NA
HW02	Raw	Incomplete	Arsenic[11]	0.0063	9E-04	**3**	NC	0.18	**2E-04**
HW02	Raw	Incomplete	Uranium[12]	0.0037	5.3E-04	**2.6***	**2.6**	0.26	**NA**
HW02	Bulk	Complete	Bromodichloromethane[5]	0.0032	4.6E-04	0.057	NC	0.0065	**4E-06**
HW02	Bulk	Complete	Chlorodibromomethane[10]	0.001	1.4E-04	0.0016	NC	0.0014	**2E-06**
HW02	Bulk	Complete	Fluoride[15]	0.79	0.11	**2.3**	NA	NA	NA
								HW02 Total Excess Cancer Risk	**6E-06**
HW03	First-draw	Incomplete	Barium[13]	1.6	0.23	**1.1**	**1.1**	NC	NA
HW03	First-draw	Incomplete	Lithium	0.041	0.0059	NA	NA	NA	NA
HW03	Raw	Incomplete	Barium[13]	1.6	0.23	**1.1**	**1.1**	NC	NA
HW03	Raw	Incomplete	Lithium	0.041	0.0059	NA	NA	NA	NA
								HW03 Total Excess Cancer Risk	NA
HW06	First-draw	Incomplete	Bromodichloromethane[5]	0.012	1.7E-03	0.21	NC	0.024	**1E-05**
HW06	First-draw	Incomplete	Dibromochloromethane[10]	0.00073	1E-04	0.0012	NC	0.001	**1E-06**
HW06	First-draw	Incomplete	Chloroform[7]	0.19	2.7E-02	**2.7**	0.27	0.09	**1E-04**
HW06	Raw	Incomplete	Arsenic[11]	0.0055	7.8E-04	**2.6**	NC	0.16	**2E-04**
HW06	Raw	Incomplete	Fluoride[15]	0.89	0.13	**2.5**	NA	NA	NA

Location	Sample Type	Exposure Pathway Complete?	Contaminant	EPC[1] (mg/L)	Oral Exposure Dose[2] (mg/kg/day)	RME HQ [2]			RME ELCR[3]
						Chronic	Intermediate	Acute	
HW06	Raw	Incomplete	Lithium	0.3	4.3E-02	NA	NA	NA	NA
								HW06 Total Excess Cancer Risk	Incomplete Pathway
HW12	First-draw	Incomplete	Arsenic[11]	0.0085	1.2E-03	**4**	NC	0.24	**2E-04**
HW12	First-draw	Incomplete	Bromodichloromethane[5]	0.0024	3.4E-04	0.043	NC	0.0049	**3E-06**
HW12	First-draw	Incomplete	Manganese	0.95	0.14	NA	NA	NA	NA
HW12	Raw	Incomplete	Arsenic[11]	0.0044	6.3E-04	**2.1**	NC	0.13	**1E-04**
HW12	Raw	Incomplete	Uranium[12]	0.0031	4.4E-04	**2.2***	**2.2**	0.22	**NA**
								HW12 Total Excess Cancer Risk	Incomplete Pathway
HW14	First-draw, raw	NA	No contaminants met or exceeded screening levels						
HW17	First-draw	Incomplete	Arsenic[11]	0.0069	9.8E-04	**3.3**	NC	0.20	**2E-04**
HW17	First-draw	Incomplete	Uranium[12]	0.0065	9.3E-04	**4.6***	**4.6**	0.46	NA
HW17	Raw	Incomplete	Arsenic[11]	0.0064	9.1E-04	**3.0**	NC	0.18	**2E-04**
HW17	Raw	Incomplete	Uranium[12]	0.0063	9E-04	**4.5***	**4.5**	0.45	NA
								HW17 Total Excess Cancer Risk	Incomplete Pathway
HW18	First-draw	Complete	Lithium	0.067	9.6E-03	NA	NA	NA	NA
HW18	Raw	Incomplete	Lithium	0.074	0.011	NA	NA	NA	NA
								HW18 Total Excess Cancer Risk	NA
HW21	First-draw, raw	NA	No contaminants met or exceeded screening levels						
HW22	First-draw, raw	NA	No contaminants met or exceeded screening levels						
HW25	First-draw	Incomplete	Methane	15000	NA	NA	NA	NA	NA
HW25	Raw	Incomplete	Barium[13]	1.6	0.23	**1.1**	**1.1**	NA	NA
HW25	Raw	Incomplete	Lithium	0.041	5.9E-03	NA	NA	NA	NA
								HW25 Total Excess Cancer Risk	NA
HW28A	First-draw	Complete	Copper[14]	0.18	0.026	NA	**2.6**	**2.6**	NA
HW28A	Raw	NA	No contaminants met or exceeded screening levels						
								HW28 Total Excess Cancer Risk	NA
HW32	First-draw	Incomplete	Arsenic[11]	0.0066	9.4E-04	**3.1**	NA	0.19	**2E-04**

Location	Sample Type	Exposure Pathway Complete?	Contaminant	EPC[1] (mg/L)	Oral Exposure Dose[2] (mg/kg/day)	RME HQ [2]			RME ELCR[3]
						Chronic	Intermediate	Acute	
HW32	Raw	Incomplete	Arsenic[11]	0.0075	1.1E-03	**3.6**	NA	0.21	**2E-04**
							HW32 Total Excess Cancer Risk		Incomplete Pathway
HW36N	First-draw	NA	No contaminants met or exceeded screening levels						
HW36N	Raw	Incomplete	Copper[14]	0.12	1.7E-02	NA	**1.7**	**1.7**	NA
							HW36 Total Excess Cancer Risk		NA
HW39	First-draw	Incomplete	Barium[13]	5.3	0.76	**3.8**	**3.8**	NA	NA
HW39	First-draw	Incomplete	Lithium	0.18	0.026	NA	NA	NA	NA
HW39	Raw	Incomplete	Barium[13]	5.3	0.76	**3.8**	**3.8**	NA	NA
HW39	Raw	Incomplete	Lithium	0.18	0.026	NA	NA	NA	NA
							HW39 Total Excess Cancer Risk		**-**
HW40	First-draw	Incomplete	Uranium[12]	0.002	2.9E-04	**1.4***	**1.4**	0.14	NA
HW40	Raw	Incomplete	Uranium[12]	0.0019	2.7E-04	**1.4***	**1.4**	0.14	NA
							HW40 Total Excess Cancer Risk		NA
HW46	First-draw	Complete	Copper[14]	0.36	0.051	NA	**5.1**	**5.1**	NA
							HW46 Total Excess Cancer Risk		NA
HW47	First-draw	NA	No contaminants met or exceeded screening levels						
HW47	Raw	Incomplete	Arsenic[11]	0.091	0.013	**43**	NA	**2.6**	**3E-03**
HW47	Raw	Incomplete	Lithium	0.08	0.011	NA	NA	NA	NA
HW47	Raw	Incomplete	Manganese	1.2	0.17	NA	NA	NA	NA
							HW47 Total Excess Cancer Risk		Incomplete Exposure
HW48	First-draw	Complete	Uranium[12]	0.0016	2.3E-04	**1.1***	**1.1**	0.11	NA
HW48	Raw	Incomplete	Uranium[12]	0.002	2.9E-04	**1.4***	**1.4**	0.14	NA
							HW48 Total Excess Cancer Risk		NA
HW49	First-draw	Complete	Copper[14]	0.14	0.02	NA	2	2	NA
HW49	First-draw	Complete	Uranium[12]	0.0018	2.6E-04	**1.3***	**1.3**	0.13	NA
HW49	Raw	Incomplete	Copper[14]	0.22	0.031	NA	**3.1**	**3.1**	NA
HW49	Raw	Incomplete	Lead	0.024	NA	NA	NA	NA	NA
HW49	Raw	Incomplete	Uranium[12]	0.0018	2.6E-04	**1.3***	**1.3**	0.13	NA
							HW49 Total Excess Cancer Risk		NA
HW52	First-draw	Incomplete	Bromodichloromethane[4]	0.0049	7E-04	0.087	NA	0.01	**6E-06**
HW52	First-draw	Incomplete	Dibromochloromethane[10]	0.00063	9E-05	0.001	NA	0.0009	**1E-06**

Location	Sample Type	Exposure Pathway Complete?	Contaminant	EPC[1] (mg/L)	Oral Exposure Dose[2] (mg/kg/day)	RME HQ [2]			RME ELCR[3]
						Chronic	Intermediate	Acute	
HW52	Raw	Incomplete	Barium[13]	2.2	0.31	**1.6**	**1.6**	NA	NA
HW52	Raw	Incomplete	Lithium	0.091	0.013	NA	NA	NA	NA
HW52	B max dup	Incomplete	Bromodichloromethane[5]	0.0065	9.3E-04	0.12	NA	0.013	**8E-06**
HW52	B max dup	Incomplete	Dibromochloromethane[10]	0.001	1.4E-04	0.0016	NA	0.0014	**2E-06**
HW52	B max dup	Incomplete	Copper[14]	0.18	0.026	NA	**2.6**	**2.6**	NA
HW52	B max dup	Incomplete	Fluoride[15]	0.8	0.11	**2.3**	NA	NA	NA
HW52	B max dup	Incomplete	Lead	0.072	NA	NA	NA	NA	NA
HW52 Total Excess Cancer Risk									Incomplete Exposure
HW53	First-draw, raw	NA	No contaminants met or exceeded screening levels						
HW56	First-draw	Complete	Manganese	0.62	0.088	NA	NA	NA	NA
HW56	First-draw	Complete	Uranium[12]	0.0015	2.1E-04	**1.1***	**1.1**	0.11	NA
HW56	Raw	Incomplete	Uranium[12]	0.0014	2E-04	**1.0***	**1.0**	0.1	NA
HW56 Total Excess Cancer Risk									NA
HW63	First-draw	Incomplete	Fluoride[15]	2.4	0.34	**6.8**	NA	NA	NA
HW63	Raw	Incomplete	Manganese	1.1	0.16	NA	NA	NA	NA
HW63 Total Excess Cancer Risk									NA
HW64	Raw	NA	No contaminants met or exceeded screening levels						

1. EPC – Exposure Point Concentration; ATSDR used the maximum concentration detected as the EPC.
2. RME = Reasonable Maximum Exposure dose and Hazard Quotient for birth to <1 yr age interval
3. Excess Cancer Risk Level (ECRL) – 33 year exposure: 21 yrs as child and 12 yrs as adult
4. Di(2-ethylhexyl)phthalate: Chronic RfD: 0.02 mg/kg/day; Intermediate MRL: 0.0001 mg/kg/day; Acute MRL: 0.003 mg/kg/day; CSF: 0.014 $(mg/kg/day)^{-1}$
5. Bromodichloromethane: Chronic MRL: 0.008 mg/kg/day); Intermediate MRL: NA; Acute MRL: 0.07 mg/kg/day; CSF: 0.062 $(mg/kg/day)^{-1}$
6. Carbon Tetrachloride: Chronic RfD: 0.004 mg/kg/day); Intermediate MRL: 0.007 mg/kg/day; Acute MRL: 0.02 mg/kg/day; CSF: 0.07 $(mg/kg/day)^{-1}$
7. Chloroform: Chronic MRL: 0.01 mg/kg/day; Intermediate MRL: 0.1 mg/kg/day; Acute MRL: 0.3 mg/kg/day; CSF: 3.1E-02 $(mg/kg/day)^{-1}$
8. Vinyl Chloride: Chronic MRL: 0.003 mg/kg/day; Intermediate MRL: NA; Acute MRL: NA; CSF: 1.4 $(mg/kg/day)^{-1}$ (this CSF is for exposure from birth)
9. 1,2-Dibromoethane (EDB): Chronic RfD: 0.009 mg/kg/day; Intermediate MRL: NA; Acute MRL: NA; CSF: 2 $(mg/kg/day)^{-1}$
10. Dibromochloromethane: Chronic MRL: 0.09 mg/kg/day; Intermediate MRL: NA; Acute MRL: 0.1 mg/kg/day; CSF: 0.084 $(mg/kg/day)^{-1}$
11. Arsenic: Chronic MRL: 0.0003 mg/kg/day; Intermediate MRL: NA; Acute MRL: 0.005 mg/kg/day; CSF: 1.5 $(mg/kg/day)^{-1}$
12. Uranium (soluble salts): Chronic RfD: 0.003 mg/kg/day; Intermediate MRL: 0.0002 mg/kg/day; Acute MRL: 0.002 mg/kg/day; CSF: NA
   * The intermediate MRL was used to derive the chronic HQ because the chronic RfD is higher the intermediate MRL
13. Barium: Chronic MRL; 0.2 mg/kg/day: Intermediate MRL: 0.2 mg/kg/day; Acute MRL; NA: CSF: NA
14. Copper: Chronic MRL; NA: Intermediate MRL: 0.01 mg/kg/day; Acute MRL; 0.01 mg/kg/day: CSF: NA
15. Fluoride: Chronic MRL: 0.05 mg/kg/day, Intermediate MRL: NA, Acute MRL: NA, CSF= NA (use MRL for sodium fluoride)

NA = Not Applicable. Bolding indicates that the value met or exceeded the derived hazard quotient or cancer risk.

Table D.4: Results of the SHOWER Model: Inhalation and Dermal Contact

-				Inhalation			Dermal		
Location	**Sample Type**	**Contaminant**	**Water EPC (mg/L)**	**Air Conc* (µg/m³)**	**Non-Cancer HQ***	**ECRL†**	**Dermal Dose ǂ (mg/kg/day)**	**Non-Cancer HQ ǂ**	**ECRL§**
HW01	First-draw	Bis(ethylhexyl)phthalate[1]	0.0035	NA	NA	NA	8E-03	0.4	**4E-05**
HW01	First-draw	Bromodichloromethane[2]	0.013	2.1	0.03	**5E-05**	2E-05	0.003	6E-07
HW01	First-draw	Carbon tetrachloride[3]	0.00057	0.088	0.0004	3E-07	4E-06	0.001	1E-07
HW01	First-draw	Chloroform[4]	0.67	112	**1**	**2E-03**	2E-03	0.15	**2E-05**
HW01	First-draw	Vinyl Chloride[5]	0.00032	0.06	0.0006	4E-07	6E-07	0.0002	3E-07
HW01	Raw	1,2-Dibromoethane (EDB)[7]	0.00068	0.11	0.01	**4E-05**	1E-06	0.0001	8E-07
HW01	Raw	Bromodichloromethane[2]	0.013	2.1	0.03	**5E-05**	2E-05	0.003	6E-07
HW01	Raw	Carbon Tetrachloride[3]	0.00054	0.083	0.03	3E-07	4E-06	0.0009	1E-07
HW01	Raw	Chlorodibromomethane[6]	0.00064	0.1	0.001	**1E-06**	1E-06	0.00001	3E-08
HW01	Raw	Chloroform[4]	0.59	98	**1**	**1E-03**	1E-03	0.1	**2E-05**
HW01	Raw	Vinyl Chloride[5]	0.00026	0.05	0.0005	3E-07	5E-07	0.0002	3E-07
								HW01 Total Excess Cancer Risk	**6E-05**
HW02	First-draw, raw	No contaminants detected, met, or exceeded screening levels							
HW02	Bulk	Bromodichloromethane[2]	0.0032	0.53	0.006	**1E-05**	6E-06	0.0008	1E-07
HW02	Bulk	Chlorodibromomethane[6]	0.001	0.16	0.002	**2E-06**	2E-06	0.00002	6E-08
								HW02 Total Excess Cancer Risk	2E-07
HW06	First-draw	Bromodichloromethane[2]	0.012	4	0.05	**1E-04**	2E-05	0.003	5E-07
HW06	First-draw	Dibromochloromethane[6]	0.00073	0.24	0.003	**3E-06**	1E-06	0.00001	4E-08
HW06	First-draw	Chloroform[4]	0.19	64	0.7	**9E-04**	4E-04	0.04	**5E-06**
HW06	Raw	No volatile contaminants							
								HW06 Total Excess Cancer Risk	**6E-06**
HW12	First-draw	Bromodichloromethane[2]	0.0024	0.4	0.005	**1E-05**	4E-06	0.0005	1E-07
HW12	Raw	No volatile contaminants							
								HW12 Total Excess Cancer Risk	1E-07
HW52	First-draw	Bromodichloromethane[2]	0.0049	0.81	0.01	**2E-05**	9E-06	0.001	2E-07
HW52	First-draw	Dibromochloromethane[6]	0.00063	0.1	0.001	**1E-06**	1E-06	0.00001	4E-08

--				Inhalation			Dermal		
Location	**Sample Type**	**Contaminant**	**Water EPC (mg/L)**	**Air Conc* (μg/m³)**	**Non-Cancer HQ***	**ECRL†**	**Dermal Dose ǂ (mg/kg/day)**	**Non-Cancer HQ ǂ**	**ECRL§**
HW52	Raw	No volatile contaminants							
HW52	Duplicate-Bulk	Bromodichloromethane[2]	0.0065	1.1	0.01	**3E-05**	1E-05	0.001	3E-07
HW52	Duplicate-Bulk	Dibromochloromethane[6]	0.001	0.16	0.002	**2E-06**	2E-06	0.00002	6E-08
								HW52 Total Excess Cancer Risk	4E-07

Table notes
* The concentration in air derived using the ATSDR SHOWER model using the appropriate household size for each residence – the HQ was derived by dividing the air concentration by the appropriate health guideline (MRL or RfC)
† The Excess Cancer Risk Level (ECRL) for inhalation exposure was derived by multiplying the maximum inhalation concentration by the IUR and adjusting for lifetime exposure for a child aged 1-20 yrs (20 yrs/33 yrs) or an adult (33 yrs/78 yrs). The child and adult CRs were summed.
ǂ The Dose and Hazard Quotient are associated with the 1 to <2 years old age group – the most highly exposed group.
§ The CR for dermal exposure was derived by calculating a cancer risk for each appropriate age interval by multiplying the appropriate exposure dose by the slope factor and adjusting for lifetime exposure (exposure duration/78 years). The CRs for the child and adult age intervals were summed.
1. Bis(2-ethylhexyl)phthalate: Inhalation: chronic MRL= NA; IUR = 2.4E-06: Dermal: RfD = 0.02 mg/kg/day; CSF = 0.014 $(mg/kg/day)^{-1}$
2. Bromodichloromethane: Inhalation: RfC (from Cal DTSC): 80 $\mu g/m^3$; IUR: 3.7E-05 $(\mu g/m^3)^{-1}$ (from EPA Regional Screening Level table): Dermal: chronic MRL = 0.008 mg/kg/day; CSF = 0.062 $(mg/kg/day)^{-1}$
3. Carbon tetrachloride: Inhalation: chronic MRL = 190 $\mu g/m^3$; IUR = 6E-06 $(\mu g/m^3)^{-1}$: Dermal: chronic RfD = 0.004 mg/kg/day; CSF = 0.07 $(mg/kg/day)^{-1}$
4. Chloroform : Inhalation: chronic MRL = 98 $\mu g/m^3$; IUR = 2E-05 $(\mu g/m^3)^{-1}$: Dermal: chronic MRL = 0.01 mg/kg/day; CSF = 3.1E-02 $(mg/kg/day)^{-1}$
5. Vinyl chloride: Inhalation: RfC = 100 $\mu g/m^3$; IUR = 8.8E-06 $(\mu g/m^3)^{-1}$: Dermal: chronic MRL = 0.003 mg/kg/day; CSF = 1.4 $(mg/kg/day)^{-1}$
6. Chlorodibromomethane: Inhalation: RfC (from Cal DTSC): 80 $\mu g/m^3$ IUR = 2.1E-05 $(\mu g/m^3)^{-1}$ (from CAL DTSC): Dermal: chronic MRL = 0.09 mg/kg/day; CSF = 0.084 $(mg/kg/day)^{-1}$
7. 1,2-Dibromoethane (EDB): Inhalation: RfC = 9 $\mu g/m^3$; IUR = 6E-04 $(\mu g/m^3)^{-1}$: Dermal: RfD=0.009 mg/kg/day; CSF = 2 $(mg/kg/day)^{-1}$
NA = Not Applicable. Bolding indicates that the value met or exceeded the derived hazard quotient of 1 or cancer risk of 1x10-6.

Table D.5: Exposure Dose, Hazard Quotient, Cancer Risk – Dimock Water

-				Oral		Inhalation		Dermal	
Location	**Sample Type**	**Contaminant**	**EPC in Water (mg/L)**	**RME HQ[2]**	**RME ECRL[2]**	**RME HQ[2]**	**RME ECRL[2]**	**RME HQ[2]**	**RME ECRL[2]**
HW01	Raw	Bis(2-ethylhexyl)phthalate[3]	0.0035	0.025	9E-07	NA	NA	0.4	**4E-05**
HW01	Raw	Bromodichloromethane[4]	0.013	0.23	**2E-05**	0.03	**5E-05**	0.003	6E-07
HW01	Raw	Chloroform[6]	0.67	**9.6**	**6E-04**	1	**2E-03**	0.15	**2E-05**
HW01	Raw	Iron	0.78	NA	NA	NA	NA	NA	NA
HW01	Raw	Vinyl Chloride[7]	0.00032	0.015	**9E-06**	0.0006	4E-07	0.0002	3E-07
HW01D	Raw	1,2-Dibromoethane (EDB)[8]	0.00068	0.011	**3E-05**	0.01	**4E-05**	0.0001	8E-07
HW01D	Raw	Bromodichloromethane[4]	0.013	0.23	**2E-05**	0.03	**5E-05**	0.003	6E-07
HW01D	Raw	Chlorodibromomethane[9]	0.00064	0.001	**1E-06**	0.001	**1E-06**	0.00001	3E-08
HW01D	Raw	Chloroform[6]	0.59	**8.4**	**5E-04**	1	**1E-03**	0.1	**2E-05**
HW01D	Raw	Vinyl Chloride[7]	0.00026	0.012	**7E-06**	0.0005	3E-07	0.0002	3E-07
							HW01 Total Excess Cancer Risk	**1E-03**	
HW02	First-draw	Fluoride[14]	0.78	**2.2**	NA	NA	NA	NA	NA
HW02	Raw	Arsenic[10]	0.0063	**3**	**2E-04**	NA	NA	NA	NA
HW02	Raw	Iron	0.97	NA	NA	NA	NA	NA	NA
HW02	Raw	Uranium[11]	0.0037	**2.6***	NA	NA	NA	NA	NA
HW02	Bulk	Bromodichloromethane[4]	0.0032	0.057	**4E-06**	0.006	**1E-05**	0.0008	1E-07
HW02	Bulk	Chlorodibromomethane[9]	0.001	0.0016	**2E-06**	0.002	**2E-06**	0.00002	6E-08
HW02	Bulk	Fluoride[14]	0.79	**2.3**	NA	NA	NA	NA	NA
							HW06 Total Excess Cancer Risk	**1E-05**	
HW03	First-draw	Barium[12]	1.6	**1.1**	NA	NA	NA	NA	NA
HW03	First-draw	Lithium	0.041	NA	NA	NA	NA	NA	NA
HW03	First-draw	Methane	11	NA	NA	NA	NA	NA	NA
HW03	Raw	Barium[12]	1.6	**1.1**	NA	NA	NA	NA	NA
HW03	Raw	Lithium	0.041	NA	NA	NA	NA	NA	NA
HW03	Raw	Methane	12	NA	NA	NA	NA	NA	NA
HW06	First-draw	Bromodichloromethane[4]	0.012	0.21	**1E-05**	0.05	**1E-04**	0.003	5E-07
HW06	First-draw	Dibromochloromethane[9]	0.00073	0.0012	**1E-06**	0.003	**3E-06**	0.00001	4E-08
HW06	First-draw	Chloroform[6]	0.19	**2.7**	**1E-04**	0.7	**9E-04**	0.04	**5E-06**

--				Oral		Inhalation		Dermal	
Location	**Sample Type**	**Contaminant**	**EPC in Water (mg/L)**	**RME HQ[2]**	**RME ECRL[2]**	**RME HQ[2]**	**RME ECRL[2]**	**RME HQ[2]**	**RME ECRL[2]**
HW06	Raw	Arsenic[10]	0.0055	**2.6**	**2E-04**	NA	NA	NA	NA
HW06	Raw	Fluoride[14]	0.89	**2.5**	NA	NA	NA	NA	NA
HW06	Raw	Iron	0.93	NA	NA	NA	NA	NA	NA
HW06	Raw	Lithium	0.3	NA	NA	NA	NA	NA	NA
HW06	Raw	Methane	13	NA	NA	NA	NA	NA	NA
							HW06 Total Excess Cancer Risk	**1E-03**	
HW12	First-draw	Arsenic[10]	0.0085	**4**	**2E-04**	NA	NA	NA	NA
HW12	First-draw	Bromodichloromethane[4]	0.0024	0.043	**3E-06**	0.005	**1E-05**	0.0005	1E-07
HW12	First-draw	Manganese	0.95	NA	NA	NA	NA	NA	NA
HW12	Raw	Arsenic[10]	0.0044	**2.1**	**1E-04**	NA	NA	NA	NA
HW12	Raw	Iron	1.4	NA	NA	NA	NA	NA	NA
HW12	Raw	Methane	13	NA	NA	NA	NA	NA	NA
HW12	Raw	Uranium[11]	0.0031	**2.2***	NA	NA	NA	NA	NA
							HW12 Total Excess Cancer Risk	**1E-05**	
HW14	No COCs								
HW17	No COCs								
HW17	First-draw	Arsenic[10]	0.0069	**3.3**	**2E-04**	NA	NA	NA	NA
HW17	First-draw	Uranium[11]	0.0065	**4.6***	NA	NA	NA	NA	NA
HW17	Raw	Arsenic[10]	0.0064	**3.0**	**2E-04**	NA	NA	NA	NA
HW17	Raw	Uranium[11]	0.0063	**4.5***	NA	NA	NA	NA	NA
HW18	First-draw	Lithium	0.067	NA	NA	NA	NA	NA	NA
HW18	Raw	Lithium	0.074	NA	NA	NA	NA	NA	NA
HW21	First-draw	Iron	1.4	NA	NA	NA	NA	NA	NA
HW21	Raw	Iron	1.1	NA	NA	NA	NA	NA	NA
HW22	No COCs								
HW25	First-draw	Methane	15	NA	NA	NA	NA	NA	NA
HW25	Raw	Barium[12]	1.6	**1.1**	NA	NA	NA	NA	NA
HW25	Raw	Lithium	0.041	NA	NA	NA	NA	NA	NA
HW25	Raw	Methane	11	NA	NA	NA	NA	NA	NA
HW28A	First-draw	Copper[13]	0.18	**2.6** (Int HQ)	NA	NA	NA	NA	NA

--				Oral		Inhalation		Dermal	
Location	**Sample Type**	**Contaminant**	**EPC in Water (mg/L)**	**RME HQ[2]**	**RME ECRL[2]**	**RME HQ[2]**	**RME ECRL[2]**	**RME HQ[2]**	**RME ECRL[2]**
HW32	First-draw	Arsenic[10]	0.0066	**3.1**	**2E-04**	NA	NA	NA	NA
HW32	Raw	Arsenic[10]	0.0075	**3.6**	**2E-04**	NA	NA	NA	NA
HW36N	Raw	Copper[13]	0.12	**1.7** (Int HQ)	NA	NA	NA	NA	NA
HW39	First-draw	Barium[12]	5.3	**3.8**	NA	NA	NA	NA	NA
HW39	First-draw	Lithium	0.18	NA	NA	NA	NA	NA	NA
HW39	Raw	Barium[12]	5.3	**3.8**	NA	NA	NA	NA	NA
HW39	Raw	Lithium	0.18	NA	NA	NA	NA	NA	NA
HW40	First-draw	Uranium[11]	0.002	**1.4***	NA	NA	NA	NA	NA
HW40	Raw	Uranium[11]	0.0019	**1.4***	NA	NA	NA	NA	NA
HW46	First-draw	Copper[13]	0.36	**5.1** (Int HQ)	NA	NA	NA	NA	NA
HW47	Raw	Arsenic[10]	0.091	**43**	**3E-03**	NA	NA	NA	NA
HW47	Raw	Iron	4.9	NA	NA	NA	NA	NA	NA
HW47	Raw	Lithium	0.08	NA	NA	NA	NA	NA	NA
HW47	Raw	Manganese	1.2	NA	NA	NA	NA	NA	NA
HW48	First-draw	Uranium[11]	0.0016	**1.1***	NA	NA	NA	NA	NA
HW48	Raw	Uranium[11]	0.002	**1.4***	NA	NA	NA	NA	NA
HW49	First-draw	Copper[13]	0.14	**2** (Int HQ)	NA	NA	NA	NA	NA
HW49	First-draw	Uranium[11]	0.0018	**1.3***	NA	NA	NA	NA	NA
HW49	Raw	Copper[13]	0.22	**3.1** (Int HQ)	NA	NA	NA	NA	NA
HW49	Raw	Lead	0.024	NA	NA	NA	NA	NA	NA
W49	Raw	Uranium[11]	0.0018	**1.3***	NA	NA	NA	NA	NA
HW52	First-draw	Bromodichloromethane[4]	0.0049	0.087	**6E-06**	0.01	**2E-05**	0.001	2E-07
HW52	First-draw	Dibromochloromethane[9]	0.00063	0.001	**1E-06**	0.001	**1E-06**	0.00001	4E-08
HW52	Raw	Barium[12]	2.2	**1.6**	NA	NA	NA	NA	NA
HW52	Raw	Iron	0.49	NA	NA	NA	NA	NA	NA
HW52	Raw	Lithium	0.091	NA	NA	NA	NA	NA	NA
HW52	Raw	Methane	11	NA	NA	NA	NA	NA	NA

--				Oral		Inhalation		Dermal	
Location	**Sample Type**	**Contaminant**	**EPC in Water (mg/L)**	**RME HQ²**	**RME ECRL²**	**RME HQ²**	**RME ECRL²**	**RME HQ²**	**RME ECRL²**
HW52	B (max dup)	Bromodichloromethane[4]	0.0065	0.12	**8E-06**	0.01	**3E-05**	0.001	3E-07
HW52	B (max dup)	Dibromochloromethane[9]	0.001	0.0016	**2E-06**	0.002	**2E-06**	0.00002	6E-08
HW52	B (max dup)	Copper[13]	0.18	**2.6** (Int HQ)	NA	NA	NA	NA	NA
HW52	B (max dup)	Fluoride[14]	0.8	**2.3**	NA	NA	NA	NA	NA
HW52	B (max dup)	Lead	0.072	NA	NA	NA	NA	NA	NA
HW52 Total Excess Cancer Risk								**2E-05**	
HW53	No COCs								
HW56	First-draw	Manganese	0.62	NA	NA	NA	NA	NA	NA
HW56	First-draw	Uranium[11]	0.0015	**1.1***	NA	NA	NA	NA	NA
HW56	Raw	Iron	0.39	NA	NA	NA	NA	NA	NA
HW56	Raw	Uranium[11]	0.0014	**1.0***	NA	NA	NA	NA	NA
HW63	First-draw	Fluoride[14]	2.4	**6.8**	NA	NA	NA	NA	NA
HW64	No COCs								

Notes
1. Exposure Dose and Hazard Quotient for birth to <1 yr age interval
2. Excess Cancer Risk Level (ECRL) – 33 year exposure: 21 yrs as child and 12 yrs as adult
3. Di(2-ethylhexyl)phthalate: Chronic RfD: 0.02 mg/kg/day; Intermediate MRL: 0.0001 mg/kg/day; Acute MRL:0.003 mg/kg/day; CSF: 0.014 $(mg/kg/day)^{-1}$
4. Bromodichloromethane: Chronic MRL: 0.008 mg/kg/day); Intermediate MRL: NA; Acute MRL: 0.07 mg/kg/day; CSF: 0.062 $(mg/kg/day)^{-1}$
5. Carbon Tetrachloride: Chronic RfD: 0.004 mg/kg/day); Intermediate MRL: 0.007 mg/kg/day; Acute MRL: 0.02 mg/kg/day; CSF: 0.07 $(mg/kg/day)^{-1}$
6. Chloroform: Chronic MRL: 0.01 mg/kg/day; Intermediate MRL: 0.1 mg/kg/day; Acute MRL: 0.3 mg/kg/day; CSF: 3.1E-02 $(\mu g/m^3)^{-1}$
7. Vinyl Chloride: Chronic MRL: 0.003 mg/kg/day; Intermediate MRL: NA; Acute MRL: NA; CSF: 1.4 $(mg/kg/day)^{-1}$ (this CSF is for exposure from birth)
8. 1,2-Dibromoethane (EDB): Chronic RfD: 0.009 mg/kg/day; Intermediate MRL: NA; Acute MRL: NA; CSF: 2 $(mg/kg/day)^{-1}$
9. Dibromochloromethane: Chronic MRL: 0.09 mg/kg/day; Intermediate MRL: NA; Acute MRL: 0.1 mg/kg/day; CSF: 0.084 $(mg/kg/day)^{-1}$
10. Arsenic: Chronic MRL: 0.0003 mg/kg/day; Intermediate MRL: NA; Acute MRL: 0.005 mg/kg/day; CSF: 1.5 $(mg/kg/day)^{-1}$
11. Uranium (soluble salts): Chronic RfD: 0.003 mg/kg/day; Intermediate MRL: 0.0002 mg/kg/day; Acute MRL: 0.002 mg/kg/day; CSF: NA
 * The intermediate MRL was used to derive the chronic HQ because the chronic RfD is higher the intermediate MRL
12. Barium: Chronic MRL; 0.2 mg/kg/day: Intermediate MRL: 0.2 mg/kg/day; Acute MRL; NA: CSF: NA
13: Copper: Chronic MRL; NA: Intermediate MRL: 0.01 mg/kg/day; Acute MRL; 0.01 mg/kg/day: CSF: NA
 *The intermediate MRL was used to derive the chronic HQ because a chronic MRL is not available.
14. Fluoride: Chronic MRL: 0.05 mg/kg/day, Intermediate MRL: NA, Acute MRL: NA, CSF= NA (use MRL for sodium fluoride)

NA = Not Applicable. Bolding indicates that the derived HQ met or exceeded 1 and/or the derived CR met or exceeded 1E-06.

Table D.6: THM Summary: Hazard Quotient and Cancer Risk

Location (# occupants at residence)	Sample Type	--		Oral		Inhalation		Dermal	
		Contaminant	**EPC in Water (mg/L)**	**RME HQ[2]**	**RME ECRL[2]**	**RME HQ[2]**	**RME ECRL[2]**	**RME HQ[2]**	**RME ECRL[2]**
HW01 (2)	First-draw	Bromodichloromethane[3]	0.013	0.23	**2E-05**	0.03	**5E-05**	0.003	6E-07
HW01 (2)	First-draw	Chloroform[4]	0.67	**9.6**	**6E-04**	**1**	**2E-03**	0.15	**2E-05**
HW01 (2)	First-draw	**Total THM**	-	-	**6E-04**	-	**2E-03**	-	**2E-05**
HW01 (2)	Raw	Bromodichloromethane[3]	0.013	0.23	**2E-05**	0.03	**5E-05**	0.003	6E-07
HW01 (2)	Raw	Chlorodibromomethane[5]	0.00064	0.001	**1E-06**	0.001	**1E-06**	0.00001	3E-08
HW01 (2)	Raw	Chloroform[4]	0.59	**8.4**	**5E-04**	**1**	**1E-03**	0.1	**2E-05**
-	-	**Total THM**	-	-	**5E-04**	-	**1E-03**	-	**2E-05**
HW02 (2)	Bulk	Bromodichloromethane[3]	0.0032	0.057	**4E-06**	0.006	**1E-05**	0.0008	1E-07
HW02 (2)	Bulk	Chlorodibromomethane[5]	0.001	0.0016	**2E-06**	0.002	**2E-06**	0.00002	6E-08
-	-	**Total THM**	-	-	**6E-06**	-	**1E-05**	-	2E-07
HW06 (5)	First-draw	Bromodichloromethane[3]	0.012	0.21	**1E-05**	0.05	**1E-04**	0.003	5E-07
HW06 (5)	First-draw	Dibromochloromethane[5]	0.00073	0.0012	**1E-06**	0.003	**3E-06**	0.00001	4E-08
HW06 (5)	First-draw	Chloroform[4] **Total THM**	0.19	**2.7**	**1E-04** **1E-04**	0.7	**9E-04** **1E-03**	0.04	**5E-06** **6E-06**
HW12 (2)	First-draw	Bromodichloromethane[3]	0.0024	0.043	**3E-06**	0.005	**1E-05**	0.0005	1E-07
HW52 (2)	First-draw	Bromodichloromethane[3]	0.0049	0.087	**6E-06**	0.01	**2E-05**	0.001	2E-07
HW52 (2)	First-draw	Dibromochloromethane[5]	0.00063	0.001	**1E-06**	0.001	**1E-06**	0.00001	4E-08
-	-	**Total THM**			**7E-06**	-	**2E-05**	-	2E-07
HW52 (2)	D-B	Bromodichloromethane[3]	0.0065	0.12	**8E-06**	0.01	**3E-05**	0.001	3E-07
HW52 (2)	D-B	Dibromochloromethane[5]	0.001	0.0016	**2E-06**	0.002	**2E-06**	0.00002	6E-08
-	-	**Total THM**			**1E-05**	-	**3E-05**	-	4E-07

1. Exposure Dose and Hazard Quotient for birth to <1 yr age interval
2.Excess Cancer Risk Level (ECRL) - 33 year exposure: 21 yrs as child and 12 yrs as adult
3. Bromodichloromethane: Chronic MRL: 0.008 mg/kg/day); Intermediate MRL: NA; Acute MRL: 0.07 mg/kg/day; CSF: 0.062 $(mg/kg/day)^{-1}$
4. Chloroform: Chronic MRL: 0.01 mg/kg/day; Intermediate MRL: 0.1 mg/kg/day; Acute MRL: 0.3 mg/kg/day; CSF: 3.1E-02 $(\mu g/m^3)^{-1}$
5. Dibromochloromethane: Chronic MRL: 0.09 mg/kg/day; Intermediate MRL: NA; Acute MRL: 0.1 mg/kg/day; CSF: 0.084 $(mg/kg/day)^{-1}$
NA = Not Applicable. Bolding indicates that the derived HQ met or exceeded 1 and/or the derived CR met or exceeded 1E-06.

Table D.7: Completed Exposures Summary, Hazard Type, and Associated Recommendations

Location	Contaminant(s) present above screening level	Completed Pathway (Drinking Water or Household)	Sensitive Populations	Hazard type: Noncancer, Cancer, or Potential Explosive	Recommendations
HW01	Trihalomethanes	Shower/household	N/A	Cancer	Determine appropriate amount of chlorine for disinfection*, limit amount of time storing water in bulk storage tanks, ventilate the home to reduce buildup of chloroform in indoor air
HW02	Trihalomethanes	Shower/household	N/A	Cancer	Determine appropriate amount of chlorine for disinfection*, limit amount of time storing water in bulk storage tanks, ventilate the home to reduce buildup of chloroform in indoor air
HW03	Methane†	Household	N/A	Potential Explosive	Install a vent on wellhead, treat water to remove methane, install a combustible gas meter, continue testing water for natural gases
HW06	Trihalomethanes	Shower/household	N/A	Cancer	Determine appropriate amount of chlorine for disinfection*, limit amount of time storing water in bulk storage tanks, ventilate the home to reduce buildup of chloroform in indoor air
HW12	Trihalomethanes	Shower/household	N/A	Cancer	Determine appropriate amount of chlorine for disinfection*, limit amount of time storing water in bulk storage tanks, ventilate the home to reduce buildup of chloroform in indoor air
HW18	Lithium	Drinking water	Children, residents taking lithium therapeutically	Noncancer	Run the water for at least 15-30 seconds before use to flush the water lines and/or use an alternative water source or treat water; individuals who take lithium therapeutically should

					discuss the levels of lithium in their drinking water with their physician
HW25	Methane†	Household	N/A	Potential Explosive	Install a vent on wellhead, treat water to remove methane, install a combustible gas meter, continue testing water for natural gases
HW28	Copper	Drinking water	Children	Noncancer	Run the water for at least 15-30 seconds before use to flush the water lines and/or use an alternative water source or treat water
HW46	Copper	Drinking water	Children	Noncancer	Run the water for at least 15-30 seconds before use to flush the water lines and/or use an alternative water source or treat water
HW49	Copper	Drinking water	Children	Noncancer	Run the water for at least 15-30 seconds before use to flush the water lines and/or use an alternative water source or treat water
HW52	Trihalomethanes	Shower/household	N/A	Cancer	Determine appropriate amount of chlorine for disinfection*, limit amount of time storing water in bulk storage tanks, ventilate the home to reduce buildup of chloroform in indoor air
HW56	Manganese	Drinking water	Children	Noncancer	Infants and children use bottled water or use appropriate and properly maintained water treatment system with bi-annual water quality monitoring

* = For more information on appropriate disinfection protocols, ATSDR recommends contacting the Penn State Extension in Susquehanna County at 570-278-1158 or visiting the Penn State Extension web site at https://extension.psu.edu/water/drinking-and-residential-water. The Penn State Extension Office can provide recommendations (https://extension.psu.edu/coliform-bacteria) for the continuous treatment of water with chlorine, shocking of systems to eliminate bacteria, and flushing lines to limit the levels of THM produced over time.
† = Other homes that had methane detections in their well had treatment that effectively removed methane to non-detect or less than 1 mg/L in their tap water.

Appendix E: Metals and Major Ions Toxicity Evaluations

Further details on ATSDR's methods for the conclusions drawn in the "Discussion" section of this document are discussed in greater detail below. Given that metals are not volatile, ATSDR did not evaluate inhalation and dermal exposure to these contaminants using the SHOWER model.

<u>Bromide, Iron, Lead, Lithium, and Sodium – Health Effects Assessment</u>

Bromide

Bromide was found in two first-draw samples (HW03-F at 0.24 mg/L and HW39-F at 1.4 mg/L) and three raw water samples (HW03-R at 0.25 mg/L, HW39-R at 1.5 mg/L and HW52-R at 0.56 mg/L).

Bromide is a naturally occurring trace element that can be found in potable groundwater at a median level of 0.016 mg/L (VanBriesen 2014). It also accumulates in coal, other fossil fuels, and organic-rich shale. As such, it is present in the water produced from the extraction of oil and gas from shale formations. In Pennsylvania, Marcellus shale produced water can contain bromide up to 1179 ± 558 mg/L (Hayes 2009).

Bromide has medical uses as an anticonvulsant and sedative at doses as high as 6 gm/day. It has been associated with effects on the endocrine and reproductive systems in animals exposed to high doses of bromide. The WHO recommends an Acceptable Daily Intake (ADI) of 0.4 mg/kg (WHO 2009). The maximum concentration found in the water at HW39-F is 1.5 mg/L, which corresponds to an exposure dose of 0.2 mg/kg/day for an infant and 0.05 mg/kg/day for an adult. These doses are comparable to the levels of bromide detected at HW39, especially for the infant.

The concentration of bromide in the drinking water at HW39 is comparable to the ADI, and adverse health effects are not expected to occur resulting from ingestion of drinking water at this location.

Iron

Iron concentrations in first-draw water samples (HW01-F, HW21-F, HW36N-F, HW47-F) ranged from 0.4 to 6.4 mg/L. Two tap water supplies (HW47-F, HW21-F) used as the primary drinking water source had iron concentrations exceeding the EPA secondary maximum contaminant level (SMCL[1]) of 0.3 mg/L while the other two samples, (HW01-F and HW36N-F) did not exceed the SMCL of 0.3 mg/L. Iron levels above the SMCL can leave red or orange rust stains on the sink, toilet, bathtub or shower surfaces. Water with high levels of iron can also stain clothes and dishes when washing and may have a metallic taste.

Iron is an essential nutrient that helps carry oxygen in the blood and is naturally found in soil and water. Low iron in the body can result in anemia. Iron deficiency is generally considered a greater risk than consuming too much iron. However, some individuals have a condition known as hemochromatosis (CDC 2014). Hemochromatosis is a genetic condition where the body absorbs too much iron resulting in a build-up of iron that can result in organ damage (CDC, 2014). CDC

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1 Secondary MCLs (SMCL) are not health-based values; instead, they are set for aesthetic purposes, such as staining of fixtures and clothing, and the odor and color of the water supply.

estimates that 1% to 6% of the population has hemochromatosis. People with this condition may be placed on a low-iron diet.

Tolerable Upper Limits (ULs) (IOM, 2010) are the highest level of a chemical that can be consumed daily that is unlikely to be harmful for healthy people. The ULs for iron are 40 to 45 mg/day for children and 45 mg/day for adults which correspond to intakes of 18 to 36 mg/L for children and 15 mg/L for adults. The concentration of iron at the first-draw sampling locations were below the ULS for iron at 0.4 to 6.4 mg/L.

Daily exposures to iron in all other water supplies would result in lower daily exposure doses that are not expected to result in adverse health effects for healthy individuals. Individuals with hemochromatosis that use these water supplies should discuss the iron levels in their water supply with their health care provider.

Unless a resident is on an iron-restricted diet or has been diagnosed with an iron disorder such as hemochromatosis, the amount of iron detected in Dimock water supplies assessed in the 2017 ATSDR EI, including the maximum detected iron concentration in HW47-F drinking water, is not expected to cause adverse health effects from daily exposure.

Lead

Lead in drinking water at any level should be reduced or removed if residents are at an increased risk for lead exposure. Lead in drinking water is of public health concern because of the potential neurological effects on the developing fetus and young children. There is no known safe blood lead level (BLL) in children. EPA has established a health-based goal for lead in public drinking water supplies (MCLG) of zero. The EPA action level for lead in public water supplies is 0.015 mg/L. If the action level for lead is exceeded, public water supply system must inform their customers about steps they should take to protect their health.

Twelve water supplies had detectable levels of lead in their water (raw or first-draw) ranging from 0.0011 to 0.072 mg/L, with two locations having lead detected above the action limit (0.024 at HW49-R and 0.072 at HW63-B). The bulk water is treated, however, and the first-draw lead concentration at HW49 was non-detect. The maximum exposure concentration in first-draw drinking water was at HW46-F (0.003 mg/L), but it was below the action level of 0.015 mg/L.

Chronic exposure to low lead levels in children has been shown to cause effects on the central nervous system, which can result in deficits in intelligence, behavior, and school performance. Health effects from lead exposure in children and fetuses include both physical and mental impairments, hearing difficulties, impaired neurological development, and reduced birth weights and gestational age. Some health effects from lead exposure, such as impaired academic performance and motor skills, may become irreversible and persist, even when BLLs return to below 3.5 micrograms per deciliter (μg/dL), the current CDC reference value (CDC 2019). While there is some discrepancy in the scientific literature between the exact decreases in IQ points associated with a rise in BLL in children, the weight of scientific evidence supports that there is an inverse relationship. It has been hypothesized that the age of exposure is a factor (because younger children are more susceptible to neurological disorders). More research is needed to further delineate the effect of low-level lead exposure, particularly on children (CDC 2019). Numerous studies have observed that low lead level exposure during the developmental stages can produce lifelong changes, including (but not limited to):

- Jusko, *et al.* (2008) found children's intellectual functioning at 6 years of age is impaired by blood lead concentrations well below 10 μg/dL;
- A study by Canfield, R.L., *et al*. (2003) concluded that IQ declined by 7.4 points as lifetime average BLL concentrations increased from 1 to 10 μg/dL; and,
- Lanphear, B.R. *et al*. (2005) found environmental lead exposure in children who have a BLL <7.5 μg/dL is associated with intellectual deficits.

There is insufficient animal or human study information to determine the carcinogenic risk from exposure to lead. EPA, DHHS and IARC identify lead as possibly carcinogenic or reasonably anticipated to be carcinogenic to humans (ATSDR 2007). Limited human and less than sufficient animal evidence is listed as the determination for this carcinogenic categorization. There is no conclusive proof that lead causes cancer in humans (ATSDR 2007).

Lead in First-Draw Samples

Lead was detected in thirteen water samples in Dimock, with three of them being in first-draw samples (0.0011 at HW06-F, 0.0025 at HW12-F and 0.003 at HW46-F). No safe blood lead level in children has been identified, therefore, ATSDR concludes that ingestion of lead from any water supply with detectable lead levels, including in HW46 tap water, may contribute to overall blood lead level from all lead sources.

Lead in drinking water below the action level of 15 ppb would be unlikely to be the sole cause of elevated blood lead levels. However, other factors for lead exposure may cumulatively increase the risk for lead poisoning. These factors include lower socioeconomic status, an older housing stock, and immigrant status. **If residents are concerned that their child(ren) may be at an increased risk for lead poisoning, they may consider filtering their water for lead at levels below the action level. ATSDR also recommends consistent blood lead level monitoring for residents who may be at an increased risk for an elevated blood lead level.**

Lead in Raw Water Samples

Samples of raw water from two water supplies, HW49 (well water) and HW52 (bulk water supply from storage tank), had lead levels in excess of the EPA Action Level (0.015 mg/L). Though residents in both homes consume water from these sources, lead was not detected in after treating or filtering first-draw samples collected from these kitchen taps.

HW52 water is treated with a reverse osmosis (RO) system at the kitchen tap, which effectively removes most contaminants, including lead, from the water before use. ATSDR recommends HW52 continue to use this treatment system for their drinking water.

HW49 water has no specific treatment system except a sediment filter, which removes larger particles before it reaches household taps. Based on the comparison of raw and treated water, the sediment trap is reducing lead levels in their water. However, this form of treatment may not be effective at removing all lead in the water system over time. Due to the detection of lead in the raw water, **ATSDR recommends HW49 strictly maintains and changes out their sediment filter based on manufacturer's recommendations to continue to prevent lead exposure in finished drinking water. ATSDR also recommends installing a lead-specific treatment system to further reduce the potential for lead exposures at the home.**

Lithium

Lithium is an element found in nature that is not an essential element in the body. Lithium is primarily taken into the body through the diet, but trace lithium may be found in water (ATSDR, 2012). Lithium is sometimes given by physicians for medical purposes and can have side effects such as effects on the kidneys, nervous system, cardiovascular system, endocrine system, and an upset stomach (EPA 2008). The lowest therapeutic dose associated with lithium treatment in adults is approximately 2.2 mg/kg/day for an adult (EPA 2008). We do not know if lithium can cause cancer in humans. EPA does not classify lithium as a human carcinogen. Lithium is undergoing clinical trials as part of the treatment regime in clinical cancer studies. Additionally, Cohen *et al.* (1998) reported that patients undergoing lithium therapy have lower cancer prevalence than the general population and that lithium may have a protective effect.

Three first-draw tap samples had lithium concentrations that exceeded the CV of 0.04 mg/L (HW03-F at 0.041 mg/l, HW18-F at 0.067 mg/L, HW39-F at 0.18 mg/L), with HW18-F being the only sample used as a primary source of drinking water. HW39-F had the maximum lithium concentration of 0.180 mg/L, but this well is not currently used as a source for drinking water. To determine the potential for adverse health effects, the maximum lithium exposure concentration of 0.067 mg/L was used to calculate daily exposure doses based on standard inputs for consumption of water and body weight.

The most sensitive child is the infant aged birth to < 1 year with an exposure dose of 0.01 mg/kg/day associated with the concentration of 0.067 mg/L; an adult exposure dose is 0.003 mg/kg/day. These estimated maximum lithium exposure doses exceed 0.002 mg/kg/day, the EPA Provisional Peer-Reviewed Toxicology Value (PPRTV) for lithium (EPA 2008).

A wide range of estimates for daily dietary intake of lithium are reported. Some authors report estimates for the average daily dietary intake of lithium ranging from 0.00024 to 0.0015 mg/kg/day, while another reports an average of up to 0.033 to 0.080 mg/kg/day (EPA 2008). Therapeutical doses of lithium equate to approximately 2.2 mg/kg/day for an adult, with the therapeutic dose producing some adverse health effects in some of the population (ATSDR 2012a).

The maximum lithium exposure dose of 0.01 mg/kg/day falls between the two estimates of average daily dietary intake (0.0024 to 0.080 mg/kg/day), but it exceeds the EPA PPRTV (0.002 mg/kg/day). There is very little toxicological data on lithium exposures in young children. The potential for adverse health effects in sensitive populations is uncertain because of the lack of relevant study data.

At maximum drinking water consumption levels, children and adults using water from HW18 as their primary source of drinking water would receive exposure doses exceeding the PPRTV. Due to limitations in the toxicology literature, ATSDR cannot fully evaluate the health implication of this exposure. The limited evidence indicates that lithium exposures at the levels detected in HW18 tap water may result in adverse health effects for some individuals, particularly sensitive populations. **ATSDR recommends residents using HW18 well water, and particularly sensitive populations, treat their drinking water or choose an alternative supply to reduce their lithium exposure. Residents with past lithium concentrations in excess of 40 μg/L (EPA PPRTV) should monitor lithium levels in their well and reduce exposures when levels exceed 40 μg/L.**

Sodium

Sodium is an essential nutrient used in the body for proper muscle and nerve function. Some people with medical conditions such as high blood pressure and kidney problems may be on salt-restricted diets. Sodium was detected in Dimock tap water samples ranging from non-detect to 93 mg/L. Six tap samples (only 3 used as primary drinking water sources) had sodium concentrations above the EPA advisory level of 20 mg/L, the level identified by EPA for people on sodium-restricted diets (EPA, 2003). The three drinking water samples exceeding the EPA advisory level includes HW47 at 93 mg/L (treated well water), HW02 at 53 mg/L (treated bulk water), and HW18 at 32 mg/L (untreated well water).

ATSDR used IOM ULs as the health-based screening levels for comparison: 1,500 mg/day for children and 2,300 mg/day for adults (IOM, 2005; IOM, 2010). Drinking the maximum volume of HW47 water each day would result in a sodium intake for children and adults ranging from 226 to 288 mg/day, respectively. Maximum daily sodium intake for adults and children, is estimated to be at or below 12% and 15% of the UL, respectively.

Residents who are not on a salt-restricted diet are not likely to experience adverse health effects from exposure to sodium in Dimock water supplies. However, residents on a sodium restricted diet should be aware of the contribution of sodium from drinking water and may want to regularly test their water supply for sodium, especially if their water tastes salty.

Appendix F: Radionuclides Assessment

Uranium, thorium, and radium are commonly found in the environment, along with many other naturally occurring radioactive forms (radioisotopes). Many of these naturally occurring radioactive isotopes have been present since the earth's formation. Others such as tritium (H-3) and carbon-14 (C-14) are continuously produced in the atmosphere as a result of cosmic radiation interactions. Many other radioactive elements are either produced when these undergo decay or have anthropogenic sources. ATSDR determines if the radiation and/or radioactive materials are naturally occurring using technical information and analysis.

Radioactive materials in soils are compared to similar areas and these areas are called background areas. If the measured amounts of radioactive materials at a particular location are similar to these background areas, then the assessor can usually determine the site of concern is not contaminated with these radioactive materials. If there are radioactive materials present at the site of concern that are not present in the background, then additional steps are taken to determine if a health risk is elevated. These steps are generally called a radiation dose assessment.

For the analysis of radioactive materials in water, there are no standard comparison values as the concentrations in water will depend on the source of the water. Groundwater concentrations are much different from surface water due to the chemistry of the groundwater that changes as it flows through different subsurface components. To evaluate radioactive material in water, we can either compare the detected values with the maximum contaminant level (MCL) established by EPA or estimate a radiation dose following ingestion if a MCL value is not given. The MCL only applies to public drinking water sources; however, ATSDR also uses the radiation MCL to screen private well sampling results. EPA's radiation dose limit for water ingestion is 4 millirem per year. Table F-1 shows the highest radiological contaminants detected in water samples collected in the Dimock compared to the EPA MCLs. No results exceeded the MCL. ATSDR did not do any further assessment of the radiological contaminants in water.

Table F-1. Summary of Radiological Measurements Compared to Drinking Water Standards at Dimock.

Contaminant	Maximum Dimock Sample Concentration*	EPA MCL (picocuries per liter)	Notes
Gross alpha radiation	7.5	15	-
Gross beta radiation (used for screening)	3.7	50	Additional actions required if screening value exceeded
Uranium (includes U-234, U-235, and U-238)	8.5	~20† (total)	The maximum value of the individual components may not be in the same well
Radium (sum of radium-226 and Ra-228)	4.3	5	The maximum value of the individual components may not be in the same well
Cesium-137‡	7.4	200	-
Thorium isotopes (Includes Th-228, Th-230, and Th-232)	1.1	Included in gross alpha radiation	The maximum value of the individual components may not be in the same well

* Laboratory value (picocuries per liter) reported to ATSDR

Appendix G: Comparison of Untreated Ground and Spring Water Results from 2012 EPA Sampling and 2017 ATSDR EI Sampling

Appendix G provides a summary comparison of the results of the 2012 and 2017 sampling for *only* untreated ground water and spring water. Sixty-four individual sources of ground or spring water were sampled by EPA in 2012, including multiple rounds of sampling at some locations. In 2017, twenty-five of these same 64 locations were re-sampled by ATSDR following the same procedures and analyzing for the same contaminants.

Based on percentage of exceedances and maximum detected concentrations, some variability is noted:

- A number of COCs in 2012 were not detected in any water sampled in 2017, including benzo(a)pyrene, bis(2-ethylhexyl) phthalate, cadmium, chlorophenyl-4 phenyl ether, dinitrotoluene, and hexachlorobenzene.
- The majority of the COCs in 2012 were also present above screening levels in a similar percentage of water supplies sampled in 2017, including arsenic, bromide, copper, iron, lead, lithium, manganese, sodium, uranium, bromide, chloride, and fluoride. Most COC concentrations were consistent between data sets; however, some metal and ion maximum contaminant concentrations were higher in 2017.
- Natural gases were detected less frequently and at lower concentrations in the 2017 raw well samples than in the 2012 samples.
- Petroleum-related COCs were detected in raw water samples in 2017 but were not detected in 2012 raw water samples.